CRASH2 MAINTENANCE
VOLUME I
DESCRIPTION OF RESULTS

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Final Report

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U.S. Department of Transportation
National Highway Traffic Safety Administration

CRASH2 Maintenance

Volume I—Description of Results

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16. Abstract

This document is a comprehensive report on a number of tasks related to several versions of the CRASH computer model of automobile collisions. Wilson Hill performed a series of activities designed to maintain, debug, and update several versions of CRASH.

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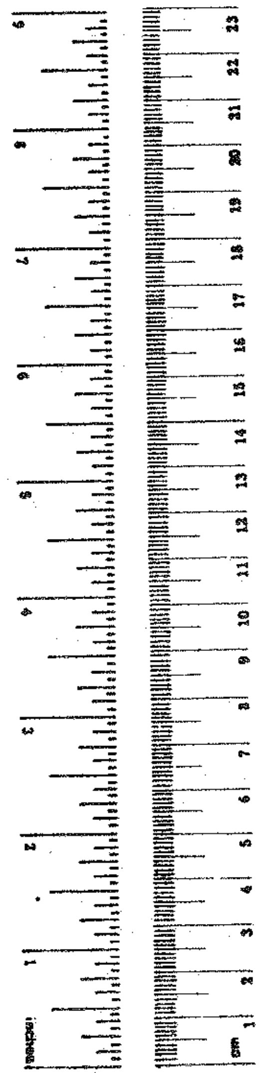
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

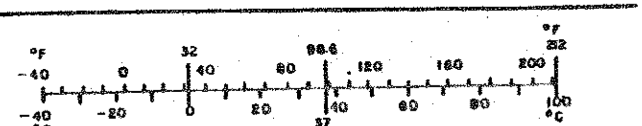
Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
	AREA			
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
	MASS (weight)			
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
	VOLUME			
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
	TEMPERATURE (exact)			
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in ≡ 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
	AREA			
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
	MASS (weight)			
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
	VOLUME			
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
	TEMPERATURE (exact)			
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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SECTION 1. INTRODUCTION

This document is a comprehensive report on a number of tasks related to several versions of the CRASH computer model of automobile collisions. Wilson Hill has performed a series of activities designed to maintain, debug, and update several versions of CRASH.

Work has been performed upon the CRASH2 production program as available under user number C0162 at MCAUTO in March 1980. A test program titled CRASH2A was also accessed in the spring of 1980 at MCAUTO under the same user number. This test program was subjected to extensive dubugging and validation during the course of the contract. In December 1980 the accumulated corrections, additions and improvements to the CRASH2A working files were assembled and edited into a new set of source files which became CRASH3. This version of CRASH3 was delivered to MCAUTO and installed by MCAUTO under user number C0162. The installed version of CRASH3 was tested by Wilson Hill prior to its release for field use on January 1, 1981. After January 1, several minor changes were outlined and coded by Wilson Hill, and passed to MCAUTO for installation in the production version of CRASH3. Each change was tested and verified in the production program by Wilson Hill. Staff at MCAUTO added an optional metric unit conversion capability to CRASH3, which Wilson Hill tested and verified.

The tasks performed began with the verification of earlier revisions to the CRASH2 code. A complete series of test runs using the 12 RICSAC staged collisions as input data was conducted to compare results between CRASH2 and CRASH2A. Coding errors were identified and corrected in both models. Analytical problems in some of the CRASH2A calculations were identified and resolved.

Concurrent to these efforts, a new set of crush coefficients (A, B, and G values) for the CRASH3 damage analysis was selected from several new sets made available by NHTSA project SRL-16. The new crush coefficients were tested, evaluated and revised before being included in the CRASH3 source code delivered to MCAUTO.

Two potential enhancements of the CRASH3 model were investigated under this contract. Raymond R. McHenry, author of the original CRASH model, evaluated a proposed braking assessment algorithm. An analysis of the prospects for incorporating a model of utility pole collisions into CRASH3 was prepared by Wilson-Hill.

All changes and corrections to the CRASH3 program described in this document have been included in the new CRASH3 program code. In addition, the CRASH3 User's Guide and Technical Manual prepared by NHTSA in the fall of 1980 was reviewed and edited to reflect the current status of the program.

The results of the tasks which have been performed are included in the following format. The next section reviews the tasks as enumerated in the contract, summarizes the results of each task, and serves as a guide to the location of relevant documentation in other parts of the report. Section 3 reviews the program changes which were made in developing the current production version of CRASH3 from the CRASH2A test program. The procedure and results of testing new A, B, and G coefficients for the CRASH3 damage analysis are described in Section 4.

Section 5 presents several possibilities for integrating a pole collision model with CRASH3. An evaluation of a braking assessment algorithm constitutes Section 6.

In Section 7 some ideas for improvements to the CRASH3 model which have evolved during the course of the present effort are listed.

Appendix 1 of this volume illustrates an input validity check performed by the CRASH3 program, and mentioned in Sections 2 and 3 of this report. Reports on Tasks 3 and 4, which were delivered previously, are included as appendices in order to form a comprehensive report.

There are two succeeding volumes to this one which present a collection of test runs executed on various versions of the CRASH program. This collection includes a complete series of the RICSAC test cases on the most recent CRASH3 release.

Throughout this document, a significant degree of familiarity with the CRASH model and associated terminology are presumed. Readers lacking such familiarity should consult other material, especially the CRASH3 User's Guide and Technical Manual which was produced by NHTSA in the fall of 1980. The User's Guide contains several references to other helpful materials. A listing of the CRASH3 source code would also be of value in interpreting parts of this report.

SECTION 2. SUMMARY OF TASKS AND ACCOMPLISHMENTS

This section summarizes each of the tasks enumerated in the contract, describes the results of each task and serves as a guide to the location of the documentation of each task within this report. It is organized by the numeric and alphabetic ordering of tasks performed under the contract.

2.1 TASK 1

This Task consisted of verifying coding changes to CRASH2 which were identified by Wilson Hill Associates as part of some prior work on the CRASH2 model. The two areas affected by the changes were input validity checking of vehicle damage index (VDI) codes and batch processing using stored, on-line disk files. Both sets of modifications were found to be in place in the CRASH2 program installed at MCAUTO. The VDI scanning subroutine from CRASH2 was modified as part of Task 2, tested, and installed in CRASH3 files which were delivered to MCAUTO in December, 1980. Appendix 1 contains a demonstration of the VDI (now termed CDC) scanning routine from the current CRASH3 production program installed at MCAUTO. The batch processing option was eliminated from CRASH3 as part of TASK 7. This was done in response to a lack of user demand for batch processing, and to make CRASH3 more economical to use.

2.2 TASK 2A

The subject of this Task was a collection of cases run on CRASH2 which showed different results when the rerun option was selected, but only the title changed. The cause of this problem in all CRASH2 runs examined was found to be SUBROUTINE PROXIM, an algorithm which checks the entered impact positions of the two vehicles in order to determine if the borders of the vehicles would be overlapping. Such overlap could reflect an error in the input data, or it could result from the use of standardized vehicle size parameters from a lookup table in the CRASH program. This overlap problem only affects CRASH when it is used as a preprocessor for the SMAC program, because CRASH calculations depend on the location of the vehicle center of gravity only. The rerun problem did not affect CRASH3 results, because PROXIM was not used in the CRASH3 program. The implemented solution to this problem is to invoke the PROXIM verification and position adjustment logic only when CRASH is being used to generate a SMAC input file. This system is used in the present CRASH3 program installed at MCAUTO. The requisite changes appear in the program code, and are described in Section 3 of this report.

2.3 TASK 2B

This Task involved the analysis and correction of a coding error documented in Volume IV, Appendix A of the RICSAC final report. The error resulted in a gross overestimation of spinout trajectory path length in those cases exhibiting a curved, non-skidding path. The presence of this error was confirmed in the CRASH2 and CRASH2A programs. A solution to the problem was developed, coded, and successfully tested. This solution involves changes to subroutines START2 and SPIN2 which are in the present program code, and described in Section 3 of this report. The proposed solution in the RICSAC report is no longer necessary.

2.4 TASK 2C

The CRASH3 program was modified to accept CDC (formerly VDI) codes conforming to the J224MAR80 standard for this Task. The changes were made to subroutine CDCSCN in the CRASH3 code. Section 3 describes the changes to CDCSCN, which have been tested and installed in the production version of CRASH3 at MCAUTO. Appendix A illustrates the operation of the CDC scanning logic.

2.5 TASK 2D

This Task identified a rerun-connected bug in the trajectory simulation logic of the CRASH program to be found and fixed. No causes of unexpected rerun alteration of results were found in the trajectory simulation code. Other sources of improper rerun changes were found to be at fault in all cases examined. These other sources of rerun problems have been identified and fixed. The requisite changes appear in the CRASH3 program code and are described in Section 3 of this report.

2.6 TASK 2E

For this Task, all possible combinations of input describing skidding, path curvature, rotation, and end of rotation points for each vehicle were examined for the occurrence of fatal FORTRAN execution errors during CRASH3 execution. Several sources of problems were identified and repaired. The present code is believed to be free of such potential execution errors which occurred when certain combinations of input data appeared. The corrections have been tested and installed in the CRASH3 program code. Section 3 describes these changes.

2.7 TASK 3

Task 3 consisted of activating the sideslip angle feature in the CRASH2A test program installed at MCAUTO, and of performing an extensive series of test runs to compare CRASH2A and CRASH2. Many problems surfaced during the performance of these test runs, which have served as the impetus for much of the subsequent work on this contract. The results of Task 3 were submitted as a separate deliverable item in April 1980. This document is included as Appendix B to Volume I of this report. The complete collection of test runs executed during the completion of Task 3 appears in Volumes II and III of the final report.

2.8 TASK 4

Task 4 identified a series of suspected programming errors in the CRASH2 code. All of the items were analyzed and corrected, if necessary. The results of this work were documented in a separate deliverable item on June 20, 1980. This document is included as Appendix C to Volume I of the final report. Any errors in the CRASH3 code which parallel the CRASH2 findings have been identified and corrected as well. Such corrections are present and have been tested in the current CRASH3 program code.

2.9 TASK 5

This Task mandated the installation and testing of updated A, B, and G damage coefficient tables in the CRASH3 program. All tables values supplied by NHTSA Project SRL-16 were installed and tested in the CRASH3 program. A final set of A, B, and G values was selected using the test results and installed in the production version of CRASH3, now available at MCAUTO. Section 4 of this report documents the damage table testing. Some changes to the input routine QUIZ, described in Section 3, were made to support new vehicle categories added to the A, B, and G tables. The test runs of CRASH3 in Volume II of the final report were made using the new damage coefficients.

2.10 TASK 6

This Task specified the incorporation of a pole collision reconstruction algorithm into the CRASH3 program. Since the pole collision model was not received in a readily incorporable form, and since NHTSA had not reached a final decision on the optimal arrangement of the two programs, the Contract Technical Manager directed that a report be prepared which explores the alternatives for joining a pole model to the present CRASH3 program. This report is included as Section 5 of Volume I of the final report.

2.11 TASK 7

A revised version of CRASH3, based on CRASH2A, was produced for this task. The coding changes were made to a work file and tested, prior to delivery of the source code files to MCAUTO in December 1980. The "CDC only" option was retained at the direction of the Contract Technical Manager, pending further discussions on what damage data should be required in all cases. Section 3 describes the coding changes which are present in the source code delivered to MCAUTO. Volume II of the report contains test runs of the production version of the CRASH3 program.

2.12 TASK 8

This Task specified an examination of the CRASH2 and CRASH2A trajectory simulation results, focusing on possible degradation of results between CRASH2 and CRASH2A. The RICSAC cases served as test data. Coding changes were made to remove execution errors, improve computation of error terms, and reduce the incidence of time out conditions in the CRASH3 program results. These changes produce simulation results and error-free execution for all of the RICSAC cases, but there is considerable progress remaining to be made in meeting the established convergence criteria. The coding changes pursuant to this task have been tested and are present in the current CRASH3 program code. These changes are described in Section 3 of the final report. Section 3 also includes a summary of the latest CRASH3 trajectory simulation results. A complete series of RICSAC runs on CRASH3 with the trajectory simulation option appears in Volume II of the final report.

2.13 TASK 9

This Task was an evaluation of a braking assessment algorithm prepared by CALSPAN FIELD SERVICES, INC. under contract number DOT-HS-5-01230. Raymond R. McHenry, of McHenry Consultants, Inc., prepared an analysis of the algorithm which appears as Section 6 of this report.

2.14 TASK 10

This final report, containing a description of results achieved and listings of test runs performed, constitutes the product of Task 10.

A source code listing of the CRASH3 program produced by this contract effort will be supplied to the Contract Technical Manager.

SECTION 3. CRASH2A TO CRASH3 PROGRAM CHANGES

This section describes the changes made to the CRASH2A test program in the process of converting it to the CRASH3 production program now installed at MCAUTO. Some changes were designed to prevent execution errors discovered while testing the CRASH2A code. Other alterations involved analytic procedures which were judged defective due to unacceptable results produced on test runs. Additions were made to support new features of CRASH3 such as the separation of vehicle crush stiffness and vehicle size descriptors, permitting a variable relation between these parameters. Modifications were also performed to update user warning and error messages and to improve the output format.

The starting point for the revisions listed below is the test program CRASH2A. The elements of CRASH2A are best documented in the final report to contract number DOT-HS-6-01442, entitled "Revision of the CRASH2 Computer Program," and authored by McHenry and Lynch. There is also an unpublished CRASH2A user's guide which may be of some value. Other CRASH2 documents should be consulted for more information on the basic structure and subroutine functions of the CRASH model. The major outline of the program has remained unchanged.

All of the changes listed here have been coded, tested, and installed in the CRASH3 production program available at MCAUTO. It would be valuable to consult a source code listing of CRASH3 in concert with this document. The CRASH3 User's Guide and Technical Manual published by NHTSA has been updated to correspond to all program modifications.

Several global changes to the CRASH program are described next. This is followed by a discussion of the revisions made for each subroutine which was altered. The subroutines are treated in the approximate order that they are used in a typical execution of CRASH3.

3.1 GLOBAL CHANGES

Throughout the CRASH3 program code, the term "VDI" has been replaced with the term "CDC," to reflect the most current NHTSA terminology. The term was changed in all occurrences, including input question text, program messages, variable names, subroutine labels, source code comments, and output listings. This comprehensive change should preclude future inconsistency and possible confusion.

The global common block labeled CRASH was expanded in every CRASH3 routine which includes it. Two variables were added to the common block. The scalar variable JSUST was added to flag those cases where sustained contact between the vehicles is indicated by the user. The vector JSTF(2) was added to store the stiffness category specified by the user for each vehicle. Nearly all subroutines within CRASH3 contain the CRASH common block which was revised.

3.2 MAIN PROGRAM

The CRASH3 main control program was edited to remove the code sections which were used to process the Batch and Document options, since these options are not included in CRASH3. The main program does not expect the value of the variable MENU, which indicates the option selected by the user, to exceed 5. The value 5 denoted Batch in CRASH2, it now denotes SMAC.

3.3 SUBROUTINE OPTION

The message output by the option selection subroutine no longer includes the BATCH or DOCUMENT options. If BATCH or DOCUMENT is entered by the user, an error message is printed. The code for processing BATCH and DOCUMENT requests has been removed. The value assigned to the variable MENU when the SMAC option is selected has been changed to 5, which corresponds to the expectation of the main program.

3.4 SUBROUTINE QUIZ

Two new questions have been added to the QUIZ input routine. One question asks the user to specify a stiffness category for each vehicle in the collision. The question has no default value, and requires a valid response in order to continue with a CRASH3 run. The valid responses range from 1 to 11, and include nine classes of vehicles and two types of crash testing barriers. The CRASH3 User's Guide and Technical Manual displays the text of this question and explains how to answer it. The stiffness category question is number 5 in the CRASH3 question sequence. The previous question 5 is now labelled question 6.

Some of the vehicle stiffness categories contain incomplete empirical damage coefficients. These categories can only be used with certain collision types, such as frontal, and not with others, such as side damage. To support this arrangement, logic has been added which accesses a lookup table stored in a new array labelled ICRSH. ICRSH has an element corresponding to each area of a vehicle (front, side, or rear) for each stiffness category. The element of ICRSH is set to value 1 if crush stiffness data exists for the specified vehicle area of the specified stiffness class, and to value 0 if data does not exist. Thus, ICRSH serves as a table of damage cases for which empirical coefficients are available. The new logic accesses the CDC supplied by the user to determine the vehicle area which has been damaged.

If the user specifies a vehicle area and stiffness class for which there is no data, an explanatory message is printed and the stiffness category question is repeated.

The user's valid responses to the stiffness question are stored as integer values in the array ISTF(2) which has been added to the common block CRASH.

The vehicle size and type categories obtained in question number 2 of the QUIZ routine have been changed to correspond to the new stiff-ness categories. However, there is no size and weight data available for stiffness classes 8 and 9. To handle this situation, logic has been added which intercepts attempts to specify a size class of 8 or 9, and directs the user to select the most appropriate value from categories 1 through 6.

Question numbers 5-7 from CRASH2A have been renumbered 6-8 in CRASH3. This was done to create space for the new stiffness question in the early part of the input sequence.

The sideslip angle questions which were suppressed in CRASH2A have been reactivated in CRASH3. Question 9 asks whether sideslipping occurred, and question 10 collects the values if question 9 is answered "yes."

The second new question added to QUIZ is numbered 11. This question asks the user whether a sustained contact spinout phase took place during the collision. The long form text of the question reviews the definition of sustained contact, which is explained in the CRASH3 User's Guide and Technical Manual. This question was added to replace an automatic test for sustained contact which was implemented in CRASH2A but found unreliable during testing with the RICSAC cases. RICSAC case 3 activated the automatic sustained contact calculation, but the diagrammed spinout paths in the RICSAC report do not bear out this result. Other RICSAC cases such as numbers 2 and 8 appear much more likely to have exhibited sustained contact, yet the automatic test was not activated when these cases were run.

The user response to the sustained contact question is YES or NO. If YES is entered, the variable JSUST is set equal to one (1) and serves to flag the sustained contact situation. If the response is negative, JSUST is assigned the value zero (0). The default response to this question is NO.

Both new questions in the QUIZ routine are coded in a style and format analogous to the existing questions. Documentation has been written for the CRASH3 User's Guide which explains and illustrates the new questions. The directing labels for backspacing and asking related questions on a rerun have been updated to handle the new arrangement.

If the sustained contact question is answered affirmatively, the trajectory simulation question is not presented, and the trajectory simulation not performed. This is so arranged because a sustained contact spinout does not satisfy the assumptions on which the trajectory time history simulation is based.

The long form text appearing in questions 39, 42, 45, and 48 was replaced with new language specifying the inclusion of induced damage in damage width measurements. This change was made to conform to the most recent NHTSA instructions and to the CRASH3 User's Guide and Technical Manual.

3.5 SUBROUTINE QUIZ2

Subroutine QUIZ2 was deleted from the CRASH3 code since it was included to perform functions only required by the BATCH option. The BATCH option is not present in CRASH3.

3.6 SUBROUTINE CDCSCN

The CDC scanning subroutine was updated to handle CDC entries made in accordance with the J224MAR80 standard. Additional characters "K" and "U" are now acceptable values for column 6 of the CDC. This change has no impact on other parts of the CRASH3 program. The clock directions for angles of force, which previously ranged from 00 to 12, range from 00 to 92 under the new guidelines. This change allows for coding a shift in the entire vehicle end structure in the CDC. CRASH3 does not presently use the structure shift information, and is set up to decode clock directions from 00 to 12 only. Subroutine CDCSCN has been modified to validate the CDC codes according to the new classification system, and then convert them to the appropriate value within the range of 00 to 12.

3.7 SUBROUTINE DAMAGE

Subroutine DAMAGE has been modified to perform energy calculations using A, B, and G values selected by stiffness category rather than wheelbase category. A stiffness category for each vehicle is stored in the vector JSTF(2), located in common block CRASH and set by subroutine QUIZ.

The logic which bypasses damage computations for barrier classifications was not correct in CRASH2A. Moving barriers were handled correctly, as class 7, but fixed barriers identified as class 8 failed to bypass the energy computations and caused FORTRAN execution errors when tested. Apparently CRASH2A was never tested with fixed barrier collisions.

In CRASH3 the barrier classification numbers are 10 for moving barriers, and 11 for fixed ones. The damage logic has been corrected to bypass energy computations for both types of barriers.

New A, B, and G values are installed in subroutine DAMAGE. The testing and selection of these values is described in Section 4 of this report.

CRASH2A featured a moment arm consistency check which compared the sign of the sum of the initial and separation angular velocities to the sign of the moment arm, H, of the damage force. CRASH2A was structured so that unequal signs led to an abrupt, undocumented, hidden exit from the CRASH2A program. This test had other problems as well. Since initial yaw velocities are always zero (0) in the present CRASH3 model, and the separation yaw velocity is not determined until after the damage analysis is complete, one of the two compared values was always zero in the CRASH2A arrangement. The only exception to this could occur on a rerun, when separation angular velocities would persist from the previous run.

CRASH3 improves the utility of this test by rearranging it to compare the user entered direction of rotation with the damage moment arm, since the user supplied value is present prior to the damage analysis. Any inconsistency of direction, indicated by opposite signs for the two indicators, generates a warning message which appears immediately and is repeated with the final printout. Execution of the program is not terminated in these cases because the test is not believed to be foolproof. Borderline cases with small moment arms and collisions characterized by certain intervehicle dynamics can lead to erroneous results from the moment arm test.

The computation of the moment arm in rear end damage cases was discovered to be incorrect in CRASH2A. Apparently, the use of negative values for distances measured toward the rear of a vehicle was overlooked when the moment arm computation was redesigned for CRASH2A. This problem has been rectified in CRASH3.

The correction factor for tangential force, in cases with damage produced by a direction of principle force not normal to a vehicle surface, was found to be miscalculated in CRASH2A. The logic in CRASH2A was retained from CRASH2, which expected a value in the range of $\pm 90^{\circ}$. However, the PDOF angle was used directly in CRASH2A, with a range of $0\text{-}360^{\circ}$. In a series of program steps, CRASH2A checks the absolute magnitude of the angle, and applies the maximum energy correction factor to all angles greater than 75°. Thus, the maximum correction would be applied in a 180°, normal, rear collision where no correction is warranted. This would distort the results by a factor of 13.9. This problem was corrected by measuring the tangent of the PDOF angle rather than the angle itself. With this arrangement the periodicity of the tangent function produces a proper result in CRASH3.

Changes were also made to bring the maximum value of the correction factor in line with the documented value of 13.9, the tangent squared of 75°. CRASH2A could erroneously pass a value of 14.9, while the correction factor reaches the specified maximum of 13.9 only in CRASH3.

3.8 SUBROUTINE START2

In CRASH2A, subroutine START2 contained many repetitive code segments. For CRASH3, the subroutine was rearranged in a loop format, with one pass performed for each vehicle.

Several complications of the treatment accorded to sideslip angles in the CRASH2A program appeared during testing performed after the sideslip angle coding was activated as part of Task 3. These problems were discussed with Thomas Noga of NHTSA and Raymond McHenry of McHenry Consultants before arriving at the following operational solution, which was installed in the CRASH3 program.

If the angle between the vehicle velocities at impact exceeds ten degrees, a linear momentum solution is produced which incorporates sideslip angles without mishap. If the velocity vector angle at impact is less than ten degrees, the linear momentum solution is bypassed and supplanted by what is termed the "axial solution." Basically, the axial solution defines impact speeds as a difference of the damage based total velocity changes and spinout derived separation velocities.

In CRASH2A, the angular discrepancy which can occur between the axial form impact velocity and the user entered impact heading is considered to be a computed or "adjusted" sideslip angle. CRASH2A repeats the impact speed calculation using the derived sideslip angle. This adjustment procedure can be iterated several times, until two successive sideslip values are equal. In RICSAC test case number 4 the solution form switched from axial to linear momentum due to sideslip angle adjustments. In cases for which the axial solution generates negative impact speeds, of which there are several among rear-end collisions with one stationary vehicle, the sideslip angle adjustment procedure becomes grossly inappropriate.

The solution adopted by CRASH3 to this problem is to bypass sideslip angle adjustment procedures unless the user specifies that sideslipping occurred in response to a QUIZ input question. If no sideslipping is specified, no adjustments occur. In these cases requiring the axial solution form, the lateral velocity change is presumed equal to the separation lateral velocity.

If the user specifies that sideslipping occurred, the entered or default sideslip angles are adjusted when the axial solution is invoked. However, only one adjustment attempt occurs, and a warning message is displayed to the user.

A section of CRASH2A code which was designed to change the entered direction of principle force in order to force agreement between the damage based lateral velocity change and the spinout based lateral separation velocity, and hence create zero slip angles when none had been specified, was removed from CRASH3. The procedure did not prove effective, and it was considered improper to alter user supplied data based on an unreliable test.

A call to subroutine OBLIQUE in cases requiring an axial form solution was removed in the transition from CRASH2A to CRASH3. The excised call had no function, as it was an unnecessary vestige of the as yet unsuccessful angular momentum solution.

START2 was also modified to appropriately measure non-skidding curved path lengths. In CRASH2A, all non-skidding paths were assumed to be straight lines. CRASH3 supports straight or curved, skidding or non-skidding trajectories.

3.9 SUBROUTINE SPIN2

An error in the computation of curved path lengths was corrected. In CRASH2A, a curved, non-skidding path produces an erroneous path length computation in SPIN2. Essentially, the program measures the entire circumference of the circle instead of correctly identifying a zero distance between two collocated points. This outcome was revised in CRASH3 to assure that appropriate path lengths are computed. If a vehicle does not skid, then the skidding path length should invariably be zero. Since START2 now computes the non-skidding path around a circle if it is curved, SPIN2 can be separated from this function and restricted to the modelling of the skidding portion of the spinout.

The changes made to subroutine START2 and SPIN2, taken together, remove any need for changes similar to those listed in the RICSAC final report, Volume IV, Appendix A. The error described there does not occur on CRASH3 runs, and so no additional data commons and associated statements are required.

The automatic test for sustained contact between vehicles during the spinout phase of a collision was removed from SPIN2. This test was found unreliable, and was replaced by a specific user input to the question of whether sustained contact occurred.

3.10 SUBROUTINE USMAC

All known execution errors resulting from the computation of error terms were precluded by appropriate code changes. Furthermore, the End of Rotation (EOR) error terms are zeroed out when no EOR data is entered by the user. The EOR adjustment factors are also disregarded when EOR data is unspecified or unavailable. These changes bring CRASH3 into closer coordination with the trajectory simulation documentation that is available.

The maximum time allowed for a vehicle to come to rest during an iteration of the time history simulation has been increased from 8 to 16 seconds. A limit of 16 seconds prevents timing out on any of the RICSAC cases.

The results obtained from test runs of the trajectory simulation after effecting these changes are displayed in Figure 3-1. Unfortunately, many of the time out and execution error results from earlier runs have been converted to outcomes of nonconvergence.

RICSAC #	1 Actual	1 C2	1 C3	1 C3+Sim.	2 Actual	2 C2	2 C3	2 C3+Sim.	6 Actual	6 C2	6 C3	6 C3+Sim.	7 Actual	7 C2	7 C3	7 C3+Sim.	8 Actual	8 C2	8 C3	8 C3+Sim
Vehicle 1																				
VX sep MPH	9.2	11.2	11.0	4.7	15.0	9.9	10.2	11.7	13.0	12.7	10.8	11.5	17.6	15.0	12.7	13.3	8.0	12.3	9.1	3.7
VY sep MPH	6.0	2.4	3.3	1.5 N	10.5	6.1	8.5	15.0 N	3.0	2.3	5.1	11.8 N	3.5	3.2	6.5	11.5 N	8.6	7.3	10.6	7.8
VΨ sep °/sec	90.0	45.3	45.3	95.7	150.0	0.0	0.0	0.0	30.0	0.0	0.0	0.0	30.0	0.0	0.0	0.0	30.0	58.6	59.6	88.8
Vehicle 2																				
VX sep MPH	7.7	10.3	10.8	2.9	N/A	10.6	9.1	11.1	10.0	7.2	6.6	9.5	15.0	8.9	7.9	14.2	13.6	17.5	15.2	14.0
VY sep MPH	-9.8	-10.3	-10.1	-13.0 N	N/A	-21.0	-21.6	-23.6 Y	-3.2	-15.4	-15.7	-14.6 Y	-8.5	-17.5	-16.2	-17.8 Y	-8.0	-6.9	-7.8	15.1
VΨ sep °/sec	0.0	23.4	48.7	19.5	90.0	45.0	45.3	33.2	180.0	137.6	137.5	145.5	192.0	171.7	171.9	183.3	192.0	53.9	46.4	47.0

	9 Actual	9 C2	9 C3	9 C3+Sim.	10 Actual	10 C2	10 C3	10 C3+Sim.	11 Actual	11 C2	11 C3	11 C3+Sim.	12 Actual	12 C2	12 C3	12 C3+Sim.
Vehicle 1																
VX sep MPH	3.5	1.1	.5	2.6	6.0	6.1	4.9	-1.5	-3.6	-3.8	-3.9	-3.7	-8.5	-8.3	-8.4	-6.3
VY sep MPH	12.0	9.8	10.6	30.1 N	22.0	19.0	17.8	17.8 N	.8	.3	.3	1.1 N	-2.2	-1.6	.6	-1.9 N
VΨ sep °/sec	180.0	0.0	0.0	0.0	300.0	116.0	115.7	134.1	-30.0	0.0	0.0	0.0	-90.0	-106.9	-107.2	-158.7
Vehicle 2																
VX sep MPH	16.2	17.4	16.6	14.2	24.5	22.3	25.8	25.8	4.8	4.8	4.7	4.7	5.5	10.7	10.9	4.8
VY sep MPH	-7.4	-10.2	-8.6	17.2 N	-11.0	-13.0	13.8	13.8 N	2.0	.2	.2	.2 Y	4.8	4.6	4.2	8.2 N
VΨ sep °/sec	-45.0	54.7	54.4	37.8	-72.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-60.0	-22.4	-22.3	-30.1

	3 Actual	3 C2	3 C3	3 C3+Sim.	4 Actual	4 C2	4 C3	4 C3+Sim.	5 Actual	5 C2	5 C3	5 C3+Sim.
Vehicle 1												
VX sep MPH	11.7	12.1	12.3	12.3	20.0	22.8	17.6	10.0	23.4	25.7	25.7	25.3
VY sep MPH	.4	.2	.2	.2 Y	-.4	4.9	4.1	14.8 N	.2	0.0	0.0	0.0 N
VΨ sep °/sec	15.0	0.0	0.0	0.0	37.0	18.2	36.1	44.7	12.0	0.0	0.0	0.0
Vehicle 2												
VX sep MPH	15.8	15.3	14.8	14.8	22.2	17.1	18.2	18.2	25.0	25.1	25.1	28.7
VY sep MPH	-.2	-2.3	-2.2	-3.7 N	-2.8	-4.4	-4.6	-4.6 N	-1.8	-4.5	-4.5	7.4 N
VΨ sep °/sec	0.0	0.0	0.0	0.0	30.0	0.0	0.0	0.0	70.0	300.5	300.1	259.0

Y = met convergence criteria
N = did not meet convergence criteria

6/24 met convergence criteria

FIGURE 3-1. TRAJECTORY RESULTS

Further modification of USMAC is necessary to improve this situation.

3.11 SUBROUTINE PRINT

The error and warning message section of the printout was revised and updated. The CRASH3 User's Guide and Technical Manual contains examples and explanations of the current warning messages.

The printout has been changed in CRASH3 to include the sideslip angles for each vehicle. These values are labelled BETA1 and BETA2. The BETA values appear in the collision data section of the long form output of CRASH3.

When no linear momentum calculations have been performed, no linear momentum output labels appear in CRASH3. In CRASH2A, the linear momentum headings are included with zero values output when the calculations have not been executed. A similar change was made to suppress printing of the impact speed headings when no impact speeds are estimable, such as in any case without trajectory data.

An error in the linear momentum speed change values for certain cases was identified and corrected. CRASH2A was subtracting an inappropriate value when determining the erroneous values. This problem has been rectified in CRASH3.

3.12 SUBROUTINE SMACIN

In CRASH2A, SMACIN outputs certain undefined variables for the impact positions of vehicles 1 and 2. In addition, improper unit conversions are applied to some of the other initial condition parameters. These parameters form input data on cards two and three of the SMAC input file. This situation appears to have resulted from a failure to update subroutine SMACIN when other changes were made during the development of CRASH2A. CRASH3 has been modified to assure that the proper variable names are in place with appropriate conversion factors applied.

SECTION 4. INSTALLATION AND TESTING OF A, B, AND G VALUES FOR DAMAGE ANALYSIS

This section presents the results of testing performed on some new sets of values for the A, B, and G coefficients used in the damage based analysis of the CRASH3 program. The A, B, and G values are empirically derived from the relation of vehicle crush damage assessments and measured speed changes in staged collision tests. In the CRASH3 program, the damage coefficients are used to estimate speed changes when vehicle crush dimensions have been collected.

The first set of new A, B, and G values tested during this contract was obtained from the September, 1980 SRL-16 progress report. The report included several sets of damage coefficients. One set was derived from staged collisions by using the CRUSH computer program, which outputs A, B, and G values based on collision damage and speed change measurements. A second set of coefficients was presented which was developed by modifying the CRUSH-based coefficients to produce a more reasonable result in low speed collisions, according to the SRL report. The exact method of adjusting these A, B, and G values was not described in the report.

Both the CRUSH-based and the adjusted values for A, B, and G appearing in the SRL-16 September, 1980 progress report were tested on the CRASH3 model. Each set of values was substituted for the existing values in the CRASH3 subroutine DAMAGE, the program recompiled, loaded and tested. The test input data was drawn from the RICSAC cases, twelve staged collisions involving 24 vehicles. The results of these test runs are displayed in Figure 4-1, along with some summary comparisons of the performance of each set of coefficients. In Figure 4-1, "NEW" refers to the SRL CRUSH-based results, while NEW(EST) refers to the SRL adjusted values for A, B, and G. The CRASH2 results, based on the old damage coefficients, are taken from the RICSAC final report.

It should be noted that some of the cases appearing in the RICSAC report were executed on CRASH2 using non-collinear angles of principle force in the input data. When these force angles are corrected, based on the measured force angles listed in the RICSAC report, the results differ significantly in those cases which involve the correction factor, $1 + \tan^2 \theta$, applied to oblique collisions. The discrepancies caused by this variation in input data are apparent in the damage coefficients test summaries for the RICSAC cases which are included later in this section. In those summaries, the differences appear between the results from CRASH2 in the RICSAC final report and CRASH2 as tested at MCAUTO in April, 1980.

The new and adjusted coefficients produced by SRL showed the most significant improvement on those cases involving rear end damage. For side impact collisions, the older table values for A, B, and G seemed to produce better results.

Based on these findings, a hybrid set of coefficients was installed in CRASH3, using SRL-generated values for front and rear stiffness, but retaining CRASH2 coefficients for side damage calculations.

In November 1980, SRL supplied some new values which were refinements of those made available in September. These values were included in the hybrid damage coefficient table described above, and became the final values installed in the CRASH3 program. The results labelled "CRASH3" in the accompanying damage test summaries are based on this set of values for A, B, and G.

SRL also calculated stiffness coefficients for some new categories of vehicles not handled by CRASH2. These new categories were pickup trucks, vans, and four wheel drive (4X4) vehicles in the September 1980 report. Later, some values for General Motors X-Body cars were supplied.

Each of these new sets of coefficients was tested against a collection of staged collision data supplied by the Contract Technical Manager

RICSAC TEST #	1	2	3	4	5	6	7	8	9	10	11	12
VEHICLE 1 AREA	F	F	F	F	F	F	F	F	F	F	F	F
CATEGORY	INT	INT	INT	INT	INT	INT	INT	INT	MINI	MINI	SUB	SUB
ACTUAL ΔV	12.2	19.6	9.5	18.7	16.3	9.2	12.0	15.3	21.4	35.1	24.0	40.1
CRASH2 ΔV	18.5	19.3	3.1	9.1	8.1	12.7	16.3	10.0	19.1	22.4	21.1	28.2
NEW ΔV	19.5	27.9	6.7	15.5	16.9	19.9	24.6	13.6	13.3	27.7	22.6	26.0
NEW(EST)ΔV	17.6	25.8	6.8	16.0	15.5	18.9	22.6	N/A	N/A	N/A	22.3	27.2
VEHICLE 2 AREA	S	S	R	R	R	S	S	S	S	S	F	F
CATEGORY	SUB	SUB	SUB	SUB	MINI	SUB	SUB	INT	INT	INT	INT	INT
ACTUAL ΔV	15.6	28.9	15.8	22.2	25.1	11.9	16.5	10.7	8.9	14.1	15.7	26.4
CRASH2 ΔV	27.7	29.0	4.9	14.1	14.8	20.9	35.5	9.5	8.8	10.9	13.2	19.6
NEW ΔV	29.2	41.8	10.6	24.2	30.7	32.6	53.6	12.9	6.1	13.5	14.2	18.0
NEW(EST)ΔV	26.5	38.7	10.8	25.1	28.2	29.9	49.3	N/A	N/A	N/A	14.0	18.8

F = Fr[illegible]

S = Si[illegible]

R = Re[illegible]

(RANKINGS OF TABLES)

	1	2	3	4	5	6	7	8	9	10	11	12
VEHICLE 1	1 E	1 O	1 E	1 E	1 N	1 O	1 O	1 N	1 O	1 N	1 N	1 O
	2 O	2 E	2 N	2 N	2 E	2 E	2 E	2 O	2 N	2 O	2 E	2 E
	3 N	3 N	3 O	3 O	3 O	3 N	3 N				3 O	3 N
VEHICLE 2	1 E	1 O	1 E	1 E	1 E	1 O	1 O	1 O	1 O	1 N	1 N	1 O
	2 O	2 E	2 N	2 N	2 N	2 E	2 E	2 N	2 N	2 O	2 E	2 E
	3 N	3 N	3 O	3 O	3 O	3 N	3 N				3 O	3 N

O = old tables

N = new crush board tables

E = new estimated tables

# CASES BEST (24 total)	
OLD	11
NEW	6
EST	7
NEW + EST	13

BY VEHICLE AREA			BY COLLISION TYPE		
SIDE(7)	FRONT(14)	REAR(3)	OBLIQUE (14)	HEAD (4)	REAR (6)
5	6	0	9	2	0
1	5	0	3	2	1
1	3	3	2	0	5
2	8	3	5	2	6

FIGURE 4-1. RESULTS OF DAMAGE TABLE TESTS

from a variety of sources. Since CRASH2 could not be used for comparisons, the new categories were evaluated on the absolute errors in estimated speed changes compared to measured results. The results of these tests appear in the damage test summaries included in this section.

Based on these test runs, the pickup, van, and X-Body coefficients were selected for inclusion in the CRASH3 program. New categories of vehicle stiffness were established to handle these cases.

The A, B, and G values for 4X4 vehicles did not produce satisfactory results in several test cases. In each of these cases, better results were obtained by using the coefficients developed for vans. The A, B, and G values for vans produced more accurate speed change estimates in every frontal impact of a 4X4 vehicle. Due to this outcome, the 4X4 coefficients were discarded. Four-wheel drive vehicles are now included in category 7, along with vans, in the present CRASH3 program.

A series of fourteen additional tests using 1980 model vehicles was run on the CRASH3 program as an additional checkout procedure. These tests span a variety of vehicle classes and include front and rear barrier impacts. The CRASH3 estimates of speed changes were generally good, with moderate errors of underestimation most frequent.

Figure 4-2 is a guide to the abbreviations for sources of A, B, and G values which appear in the accompanying test reports. Figure 4-3 lists the stiffness category codes. These are the current CRASH3 vehicle categories, with the exception of the 4X4 classification, which was merged with class 7 (vans) as detailed above.

The numeric values for A, B, and G now installed in the CRASH3 program are listed in the CRASH3 User's Guide and Technical Manual, in Section 8, Table 8-2.

LABEL	SOURCE
CRASH3	Program as released for field use, 1/1/81
CRASH2A	Experimental Program as tested in April 1980
CRASH2-R	CRASH2 results as reported in RICSAC final report
CRASH2-M	CRASH2 results from production program at MCAUTO, April 1980
CRASH2-R,M	Refers to identical results from CRASH2-R and CRASH2-M
SLR-1	A, B, G values from SRL-16 progress report, September 1980
SLR-2	Revised A, B, G values from SRL 16, by phone, November 1980

FIGURE 4-2. KEY TO A, B, G SOURCES IN SUMMARY REPORTS

LABEL	DESCRIPTION	WHEELBASE RANGE (INCHES)
1	Minicar	80.9 - 94.8
2	Subcompact	94.8 - 101.6
3	Compact	101.6 - 110.4
4	Standard	110.4 - 117.5
5	Full Size	117.5 - 123.2
6	Large	123.2 - 150.0
7	Vans	109 - 130
8	Pickup Trucks	---
9	X-Body Cars	---
4X4	Four Wheel Drive Vehicles	---

FIGURE 4-3. KEY TO STIFFNESS CATEGORIES

Appendix D includes summary reports of all damage test cases executed during the course of A, B, and G value testing. The description and damage data are reported for each vehicle, along with whatever speed measurements were available. The estimated speed change (ΔV) and source of the A, B, and G values for each test appear at the right end of the table for each vehicle. Subsequent tests are listed on succeeding lines, with any differences in input data or A, B, and G values displayed. Items for which no changes were made remain blank on successive lines.

SECTION 5. POSSIBILITIES FOR INTEGRATION OF CRASH3 AND A POLE COLLISION MODEL

This section presents an analysis of the prospects for incorporating a reconstruction technique for collisions between motor vehicles and vertical poles into the CRASH3 model of automobile collisions. The pole reconstruction methodology under consideration was developed by Southwest Research Institute (SwRI) under Contract No. DTNH22-80-C-07014 from the National Highway Traffic Safety Administration, U.S. Department of Transportation. This reconstruction methodology was documented in a final report to the contract mentioned above, and that final report has served as the source of information on the pole reconstruction procedure for the preparation of this analysis.

The SwRI pole collision model divides a collision between a vehicle and a pole into three sequential phases, estimates the velocity change attributable to each phase, and sums the components from each phase to derive a value for the total velocity change resulting from the pole-vehicle interaction. The SwRI model requires as input a collection of data descriptive of the pole, an estimate of the velocity change attributable to crushing of the vehicle structure, and an estimate of the speed at separation of the vehicle from the impact point.

The CRASH3 model of automobile collisions incorporates several analytical, iterative, and simulation based processes to derive estimates of vehicle velocities and velocity changes resulting from a collision between vehicles, or between a vehicle and a barrier. The CRASH3 input data is copius, including several items which may be supplied in response to each of some 50 questions.

In the final report on the SwRI pole collision model, it is recommended that the pole model be combined with the CRASH3 model, due to the cumbersome nature of the calculations required by the pole impact analysis. Cumbersome calculations are a good reason to automate the pole impact methodology, but this argument is for the value of automation, not for the value of combining CRASH3 and the SwRI algorithm into one unit. The question of whether to code the pole technique for ease of use is distinct from the question of whether to place such code directly in the CRASH3 program.

In fact, there are good reasons for establishing a close relationship between CRASH3 and the pole impact methodology. First, the pole reconstruction improves the results obtainable from the CRASH3 program in vehicle-pole collisions. The extant CRASH3 program can only model poles as undifferentiated from barriers of any kind. Furthermore, by definition within the CRASH3 framework, barriers do not absorb energy in structural deformation when struck by a vehicle. Thus, the addition of a pole collision modelling procedure can be seen as a correction to or refinement of the CRASH3 damage-based analysis. Such a modification would extend the scope of cases which can be usefully analyzed under the CRASH3 program assumptions.

Second, an examination of the pole reconstruction procedure reveals that several important required input variables are available in the CRASH3 output. Figure 5-1 is a schematic flowchart for the pole reconstruction process. This chart is adapted from the system flowchart presented as Figure 2 on page 15 of the SwRI final report. Two crucial inputs are the velocity change due to deformation of the vehicle structure and the vehicle velocity at separation from impact. Neither of these quantities is directly measurable at the scene of an accident. Both of these values are estimated by the CRASH3 program from data which can be collected at an accident location. Thus, the CRASH3 program output is an especially convenient source of input data that is required by the pole collision analysis.

Based on the methodology and sample calculations included in the final report on the SwRI pole accident reconstruction procedure, no significant obstacles are foreseen to an automated implementation of the pole model. It appears that a straightforward program written

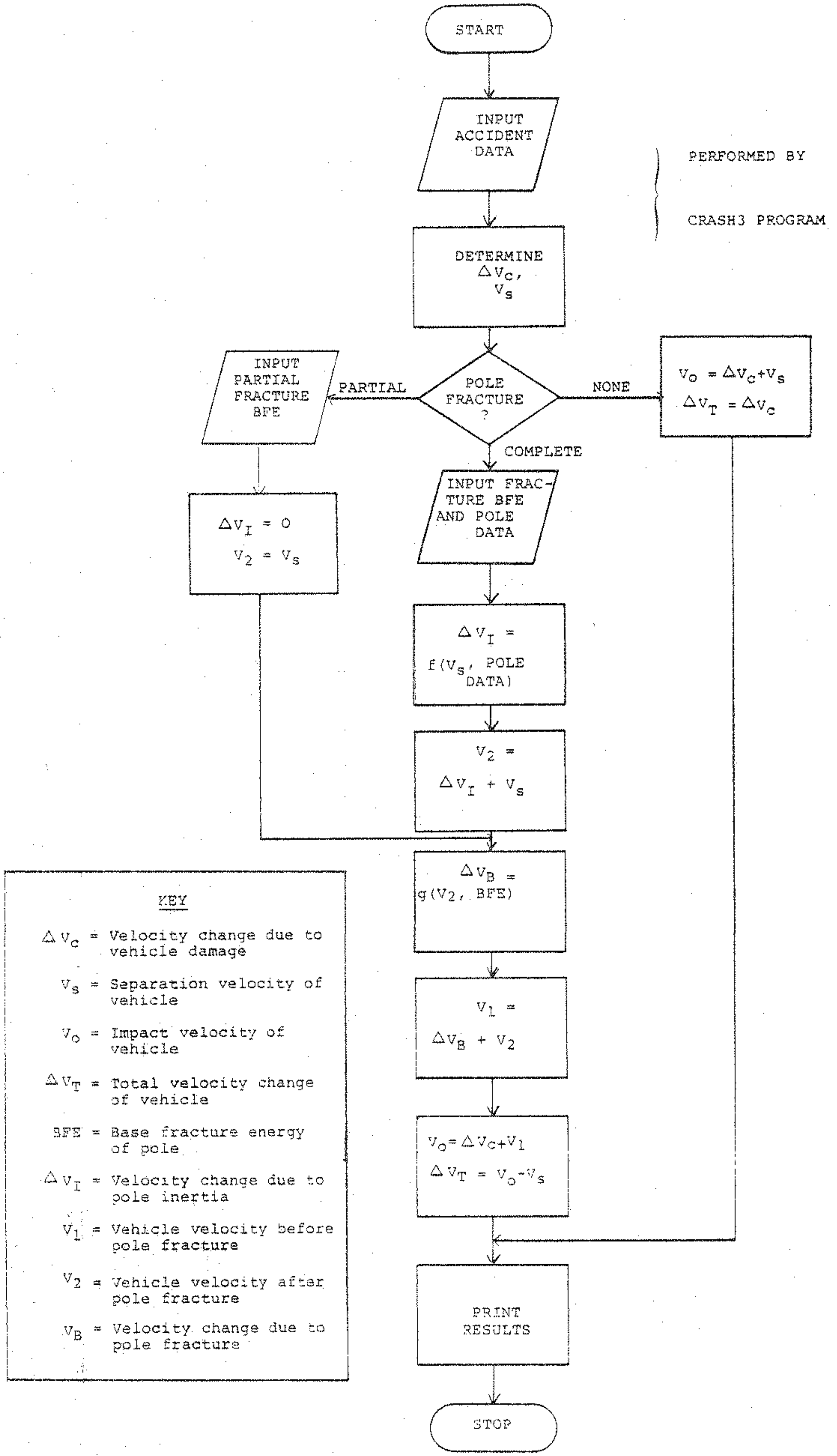

FIGURE 5-1. SCHEME OF POLE RECONSTRUCTION PROCESS

in the FORTRAN language could be developed to perform the required decisions and computations.

If it is granted that an automated pole collision model is worth developing, and if the association of such a program with the CRASH3 program is also seen to have value, the preferred nature of that association remains open to question. The following paragraphs are intended to explore this question, in the following format.

Three general approaches to an integration of the SwRI pole collision model and the CRASH3 program are discussed. The first approach is development of a separate program which performs the pole model calculations, is compatible with the CRASH3 program, uses CRASH3 results as input data, but is executed independently of CRASH3. The second scheme considered is to graft the pole model onto the CRASH3 program code as a unitary subroutine or group of subroutines, while retaining the present CRASH3 structure in large measure. The third approach discussed here is to divide the pole impact model into logical components, join each component to an appropriate part of the CRASH3 program, and modify the CRASH3 program structure to make proper use of the melded components.

Each approach is summarized below, beginning with a discussion of the details and difficulties attendant to the implementation process. Next, the user's perspective is considered. The discussion of each approach concludes with an assessment of the impact that the given combination of CRASH3 with the pole collision model will have on potential future developments of either system.

The simplest integration of CRASH3 and the SwRI pole collision procedure would be to encode the pole procedure as a separate, executable program that is designed to ensure compatibility with the CRASH3 program. Such compatability could be ensured by the selection of terminology, variables, variable names, and units of measure incorporated in the pole collision model code. It might also be useful to modify the format of the CRASH3 output presentation to make

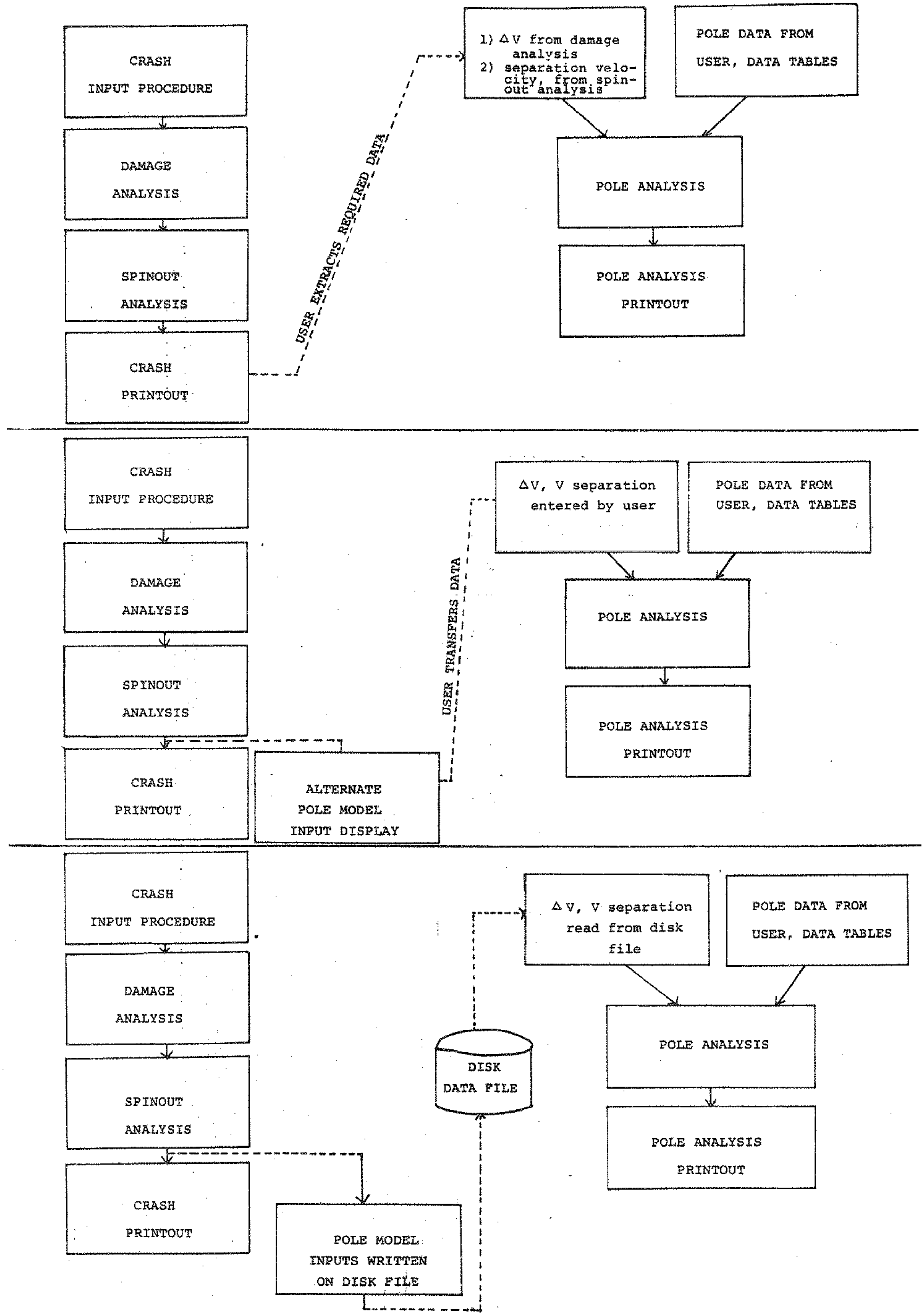

FIGURE 5-2. POTENTIAL RELATIONSHIPS BETWEEN CRASH3 AND A COMPATIBLE POLE MODEL

the input values for the pole model more accessible. For example, the separation velocities could be included in the abbreviated printout from CRASH3. Or, a separate output option could be constructed to display those values required by the pole model. A third alternative would be to pass values between the two programs in an on-line data file. Figure 5-2 illustrates some potential relations between CRASH3 and a separate pole model.

To use this type of combination of two compatible programs, the operator must issue commands to execute each program, and transfer the required data from the CRASH3 output display to the pole model input routine; unless a data file transmission system is established. None of these tasks is lengthy or difficult, but they require that the CRASH3 user segregate those cases involving pole collisions and accord them the proper special treatment.

If CRASH3 and the pole accident reconstruction techniques were maintained as separate, compatible, executable modules, there would be little or no complication of future developments in either model. As separate programs, the two models could be modified, tested, and refined without mutual interference. There would be no impact of changes in the assumptions, procedures, equations, or ordering of calculations internal to either program. The overall impact on program development costs would be minimal in this arrangement.

A second type of CRASH3-pole collision model combination would result from joining the pole collision algorithm directly to the CRASH3 program code, as a separate subroutine. In this approach, the input, processing and output functions of the pole model would reside in a subroutine or collection of subroutines grafted onto the CRASH3 program. Figure 5-3 displays a simplified flowchart of the CRASH3 program, as modified by the inclusion of a pole collision subroutine. The pole collision analysis would have to be performed after both the damage analysis and the spinout trajectory analysis are complete, since it requires input values from both of these procedures.

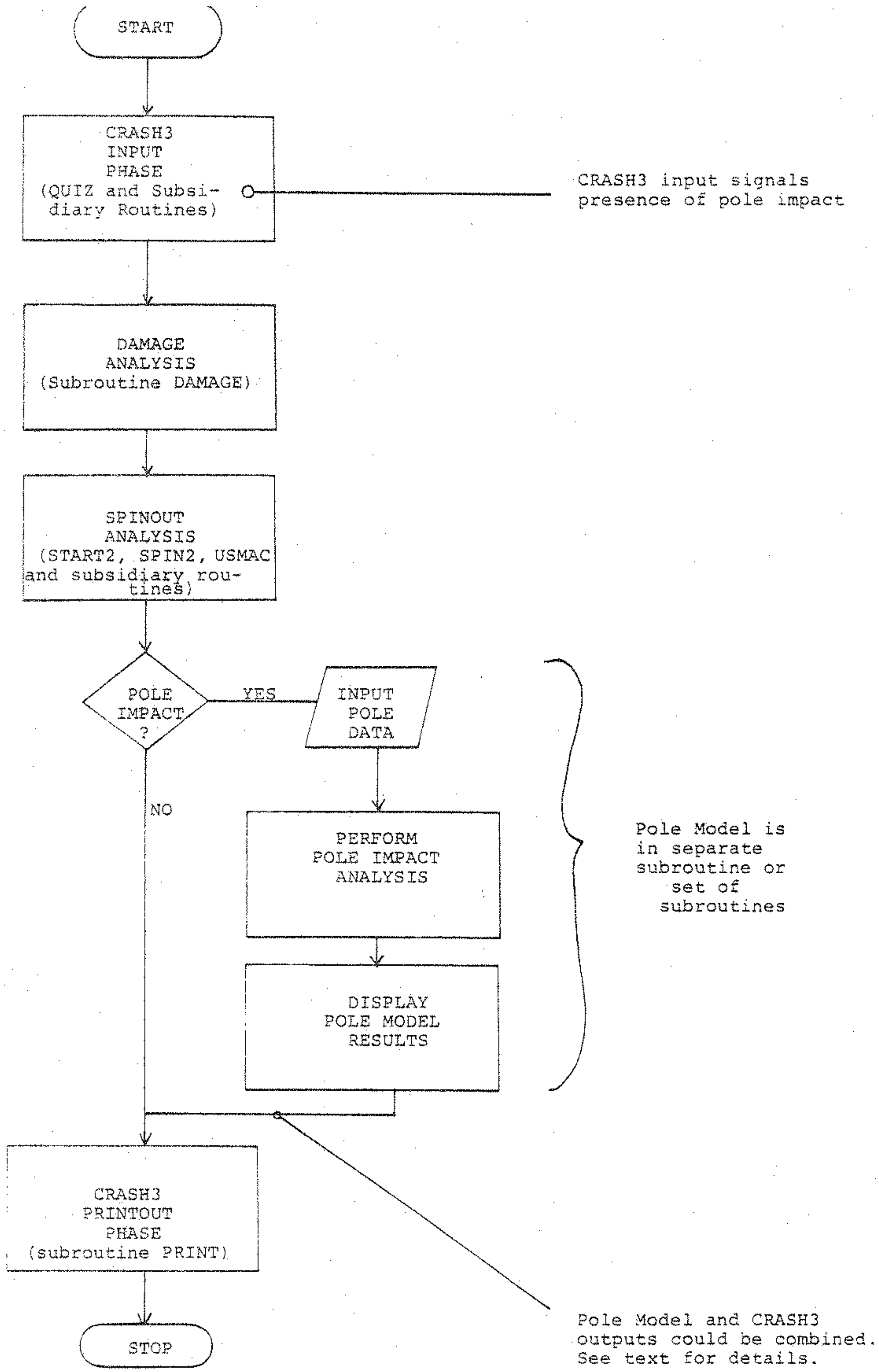

FIGURE 5-3. CRASH3 PROGRAM WITH UNITARY POLE MODEL SUBROUTINE

In this system, the pole collision subroutine could be activated at the option selection level, i.e., by adding "POLE" to the list of options such as COMPLETE, ABBREVIATED, RERUN, etc. A better alternative might be to add a question to the central input routine (QUIZ), asking whether the barrier is a pole. This question would be presented only when the barrier classification is selected by the user; as a response to the vehicle classification question which is present in the current CRASH3 program.

A third approach would be to add a new classification, similar to the immovable barrier classification, for poles. This approach would preserve the present classification format, and simply expand the range of responses. Of course, any new classifications would require changes in all subsequent subroutines of the CRASH3 program which are controlled by the classification value. The affected subroutines would be from both the damage and trajectory analyses, with some minor changes to the output system.

The input values from CRASH3 to the pole model subroutine could be communicated via common blocks now present in the program code. Additional user inputs defining the pole characteristics would be solicited by questions at the beginning of the pole collision subroutine. The pole collision subroutine is likely to contain lookup tables as additional sources of input data.

The pole collision reconstruction results could be reported in several formats. The simplest system would print out the appropriate values at the conclusion of the pole analysis, before returning control to the printout phase of the CRASH3 program. A more integrated approach would be to pass the pole model results to the CRASH3 print control subroutine, and display them in conjunction with the other CRASH3 values. This would require the addition of a common block to transmit the pole model output and of some printing and formatting statements to the CRASH3 output subroutine.

Functionally, the pole model outputs can be best viewed as corrections to the CRASH3 damage analysis results. For this reason, it might be most appropriate to construct logic which would modify the CRASH3 damage-based results according to the pole model output values. The modifications could be performed at the end of the pole analysis subroutine, and the corrected values passed to the CRASH3 printout routine via an existing common block. In this case, a message could be displayed as a preface to the CRASH3 results, which indicates when pole collision-based corrections have been made. This message capacity would require changes to the CRASH3 subroutine PRINT.

The user's burden under a separate subroutine implementation of a CRASH3-pole collision model combination would be sensitive to the details selected from the options described here. In any case, the user would be obligated to signal the necessity of performing a pole impact analysis at some point in the program operation. Furthermore, an additional, second stage of input data defining pole characteristics would need to be supplied at the terminal. Third, the user would be required to interpret the output results in accordance with some guidance on the pole collision analysis and its effects. The output interpretation necessary would depend on which of the output schemes outlined above was installed in the production program.

The CRASH3 program is large and complex. It contains many variables. Therefore, the addition of a subroutine version of the SwRI pole collision model is certain to impact future development of either model. By keeping the pole model relatively separate and self-contained, it would be possible to modify algorithms within the pole model or within one of the CRASH3 subroutines without encountering complications in the joint program. Any changes in common blocks or global variables, however, would have widespread repercussions. Such changes would require updating all portions of the source code. It is fair to say that any inclusion of the pole collision model within the CRASH3 program, even as a unitary subroutine, would significantly complicate future revisions of both models.

The third approach to combining the SwRI pole reconstruction algorithm with CRASH3 is a complete integration of the two procedures.

This would be accomplished by isolating the pole model input functions, and combining them with the present CRASH3 input routine. The pole collision model processing would be incorporated into a revised version of the damage analysis subroutine from CRASH3. In this revised damage calculation, pole impacts would form a new class of barrier-type collisions, with the pole model approximations serving to define the absorption of energy by any deformation, fracture, or dislocation of the pole.

To support the function of such a new damage analysis procedure, the CRASH3 structure would need to be reordered. The pole model requires values for the impacting vehicle's separation velocity. These values are calculated by the trajectory, or spinout, analysis of the CRASH3 program. In order to provide separation velocity estimates as input to the damage analysis, the current order of damage analysis followed by spinout analysis would have to be reversed. In pole collision cases, there would not be a problem with this structural alteration of CRASH3. However, in vehicle-to-vehicle collisions where the impact velocity vectors for the two vehicles are offset by an angle of ten degrees or less, the CRASH3 spinout analysis requires input from the damage analysis. Thus, to perform a damage analysis with pole impact reconstruction requires that the spinout analysis be completed first; to perform a spinout analysis in certain cases requires that the damage results be available. Any integration of the pole model into the CRASH3 damage analysis would be required to resolve this problem, perhaps by adding additional high level logic to the CRASH3 system. Figure 5-4A outlines a possible restructuring of the CRASH3 program under the assumption of a complete pole model integration.

Figure 5-4B illustrates a second approach to restructuring CRASH3 in order to facilitate complete integration of the pole model. This alternative begins with a division of the CRASH3 spinout analysis procedure. Currently, the spinout analysis determines separation velocities, which are then used to estimate impact speeds. The estimation of impact speeds is logically separable from the derivation of

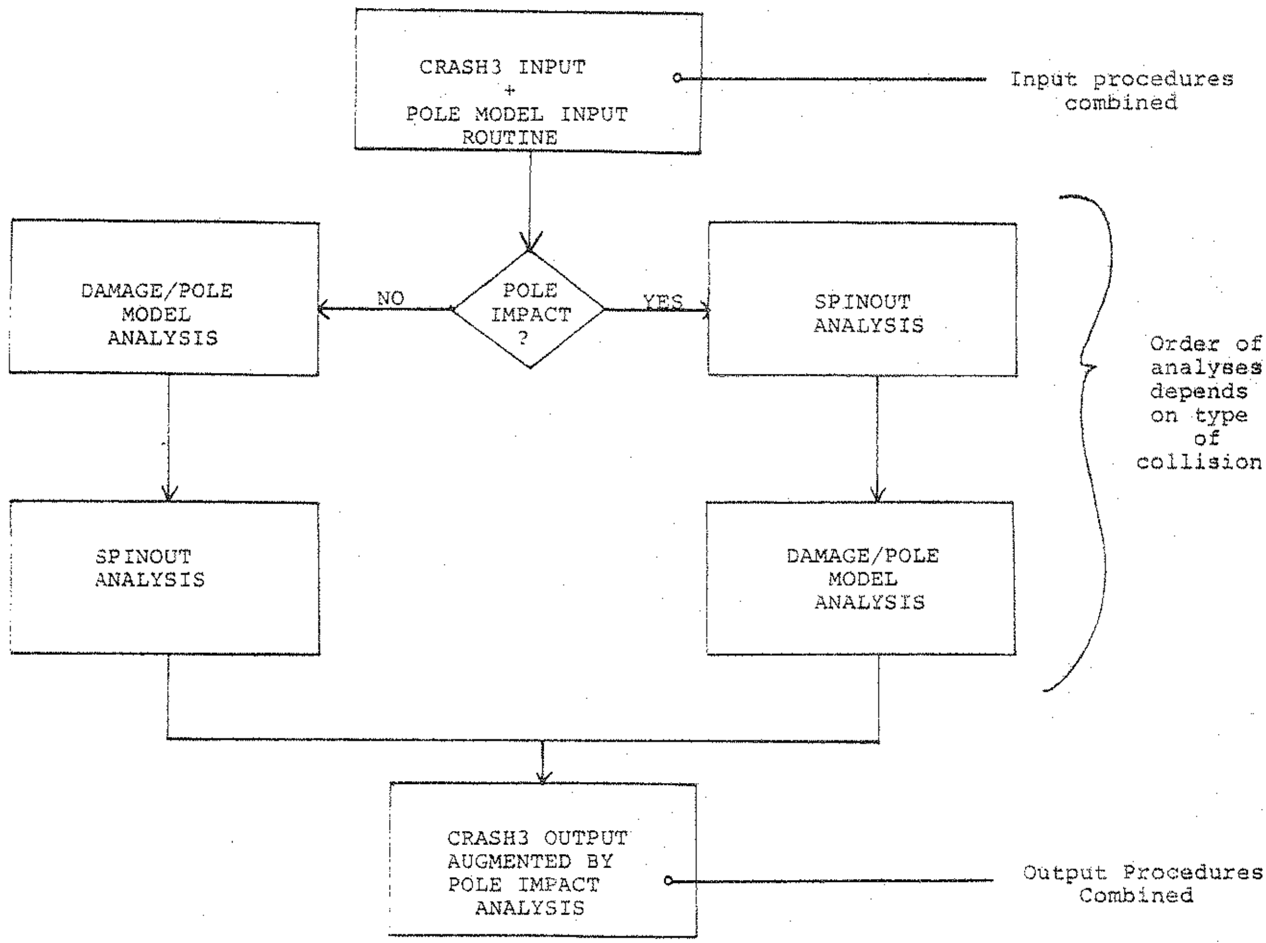

FIGURE 5-4A. POTENTIAL STRUCTURE OF A FULL INTEGRATION OF THE POLE COLLISION MODEL WITH CRASH3

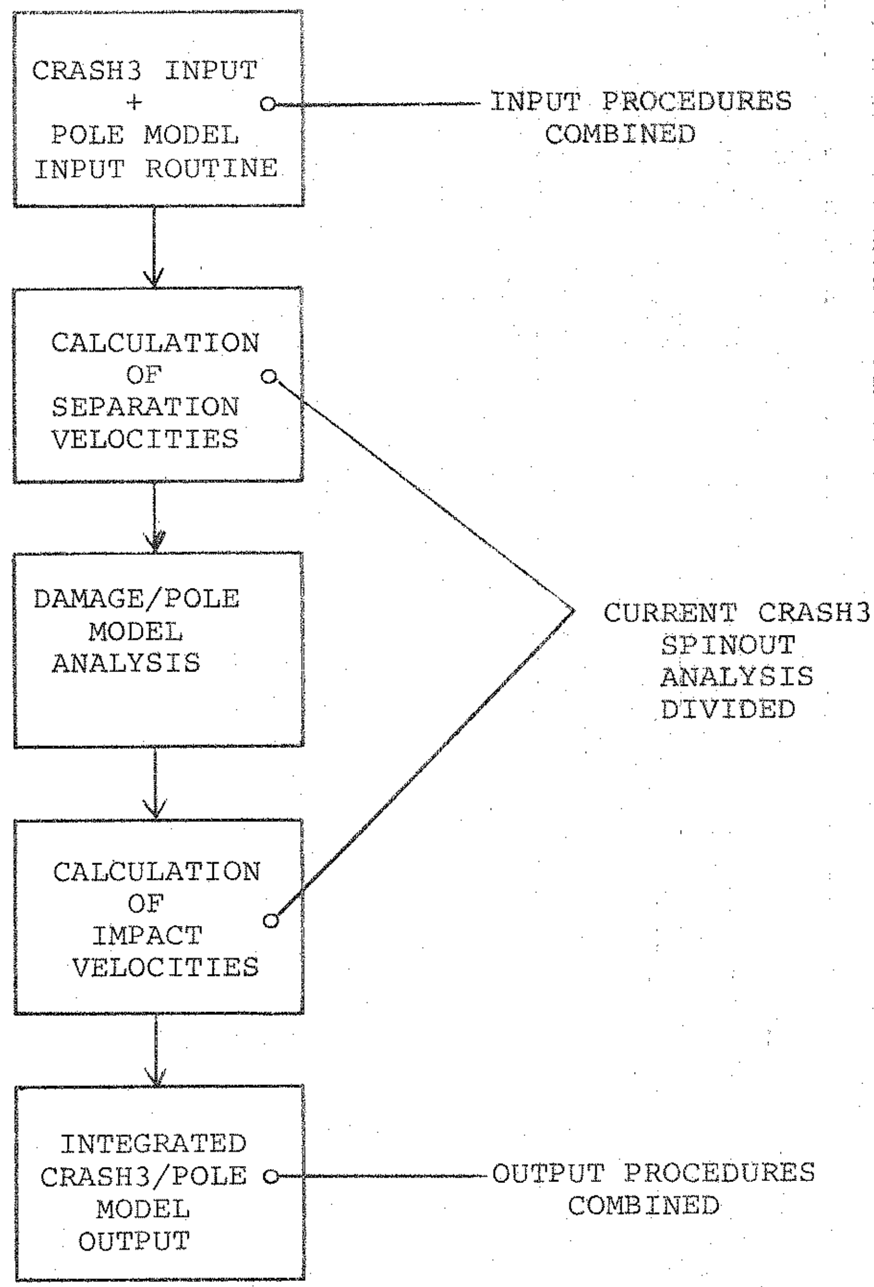

FIGURE 5-4B. ALTERNATIVE STRUCTURE FOR COMPLETE POLE MODEL - CRASH3 INTEGRATION separation velocities, although the two functions are now controlled by the same subroutine in the CRASH3 program code.

If this multipurpose subroutine were divided according to its component functions, the separation conditions could be estimated before any damage calculations are performed. With this arrangement, the pole model input data requirements could be supplied prior to the application of a combined pole model-damage analysis. The impact speed calculation would be performed after the combined pole model-damage analysis, at a point in the program when all necessary preliminary results are available. At that point, the impact speeds could be derived regardless of the collision type.

This second approach to a full integration of CRASH3 and the pole model computations would preclude high level logic procedures based on collision type in the CRASH3 code. It would, however, necessitate the dissection of subroutine START2 and other associated code changes in the CRASH3 spinout analysis as it is presently constituted.

A complete integration of CRASH3 and the pole collision model would exhibit an integrated output format. The pole model algorithm would function to improve the accuracy of the damage based results available in the current CRASH3 printout. Additional items related to a pole impact could be added to the CRASH3 output. Optionally, a message could be supplied to indicate those cases in which pole impact assumptions were invoked.

The user impact would be minimized by a complete integration and restructuring of the two models. Only the addition of poles as a class of barriers and the pole related input questions would differ from the present CRASH3 protocol. Of course, the number of supplementary inputs required to model a pole impact is quite large, no matter how the pole analysis is performed. Figure 5-5 is a reproduction of Table 1 from page 14 of the SwRI pole model final report. It lists the data requirements of the reconstruction procedure.

Minimum Requirements

Type of Pole

Material of Pole or Base

Length of Pole

Cross-sectional dimensions at base of pole

Type of base/anchoring mechanism

Type of breakaway design

Damage extent of pole

Desirable Additions

Height of break/length of broken segment

Cross-sectional dimensions at top and bottom of broken segment

Final rest position of pole

Manufacturer of breakaway device

FIGURE 5-5. DATA REQUIREMENT FOR RECONSTRUCTION PROCEDURE

If the CRASH3 and pole collision models were integrated totally, the result would be one program, necessarily larger, more complicated, and more difficult to maintain. The impact of any change to any algorithm would require careful assessment. It follows that future development of an integrated CRASH3-pole model program would be more difficult and costly than any modifications introduced into somewhat less dependent arrangements of the two procedures.

Figure 5-6 summarizes in table form the differences among the three categories of CRASH3-pole model combinations discussed above. Note that the details of a given arrangement of the two procedures are important to a determination of the degree and significance of the factors enumerated in this summary.

Figure 5-7 ranks the general approaches that have been presented, in categories according to the dimensions along which the discussions were aligned. In this ranking, with equal weights assigned to each measure, separate but compatible programs are preferred; but the distinction between the various combinations should rest on other factors, as well as an informed weighting of the items considered here.

A significant external factor is the number of pole collision cases which occur, and the proportion of all CRASH3 cases which are pole impacts. Essentially, it must be determined whether the benefit of being able to handle pole cases as a built-in CRASH3 function outweighs the costs of providing this function, and of maintaining it in the CRASH3 system during the course of processing those cases which do not involve pole impacts.

The value of user convenience must be assessed broadly as well. Reducing the user's role via automatic options cannot be appraised blindly. There may well be value in retaining the user's discretion as an input factor, at a relatively slight cost of some additional

Area of Impact	APPROACH SELECTED: Separate, Compatible Programs	Pole Model as Unitary Subroutine of CRASH3	Complete Integration of Pole Model and CRASH3 Functions
Implementation	• compatibility easily established in design • coding, debugging and testing of both programs are separable • staged implementation convenient	• common blocks, variable types & units must be coordinated • minimal restructuring of CRASH3 required • staged implementation possible	• several subroutines of CRASH3 must be rewritten • implementation requires significant restructuring of CRASH3 system • staged implementation difficult
Use	• two programs must be executed • values must be transferred from CRASH3 to Pole Model • output of two programs must be combined manually	• one program to execute • two input phases required • hybrid or two-part output display may require interpretation	• one program to execute • single, integrated input, phase • single, integrated printout
Continued Development	• no complications of changes in either program • alternate analyses tested easily in either model	• some complications likely from changes in either model • internal algorithms could be altered with minimal impact	• models must be developed jointly after integration • testing alternate routines may require widespread changes

FIGURE 5-6. SUMMARY OF FEATURES: CRASH3 - POLE COLLISION MODEL COMBINATIONS

CATEGORY	APPROACH		
	Two Programs	Unitary Subroutine	Complete Integration
Ease of Implementation	1	2	3
Simplicity of Use	3	2	1
Facility for Future Development	1	2	3
Sum of Ranks	5	6	7
Mean of Ranks	1.6	2	2.3

KEY

1 = Best

2 = Intermediate

3 = Worst

FIGURE 5-7. UNWEIGHTED RANKING OF GENERAL APPROACHES TO CRASH3 - POLE MODEL INTEGRATION tasks which must be performed. On the opposite side, automatic features make the enforcement of uniform operating policies quite simple, and this may enhance the consistency of results which are obtained.

A third external judgement which should contribute to the choice among these approaches is the potential for, and probability of, future development work on the models whose combination is under consideration. If continuing research and significant alterations are in store for either or both CRASH3 and pole reconstruction techniques, then the costs of future development that would be increased by an integration of the two programs must be weighed heavily. If, on the other hand, the models are intended to be stable, production oriented tools for the analysis of accident data, the convenience and consistency of an integrated package may be the most important factors.

Without guidance and information on these outside factors, it is not possible to make a meaningful recommendation in this matter. However, the preceding discussion can serve to illuminate and clarify some of the grounds on which a decision should rest.

SECTION 6. EVALUATION OF A BRAKING ASSESSMENT ALGORITHM

This section contains an evaluation of a braking assessment algorithm which was developed by Calspan Field Services, Inc. under Contract No. DOT-HS-5-01230 from the U.S. Department of Transportation, National Highway Traffic Safety Administration. The evaluation was performed by Raymond R. McHenry, of McHenry Consultants, Inc., under subcontract to Wilson Hill Associates. Mr. McHenry is the principle author of the original CRASH computer program.

In his evaluation, McHenry concludes that the proposed algorithm does not appear to serve a useful purpose. He recommends further study in the investigation and assessment of pre-crash events as a prelude to the construction of a suitable automated model.

6.1 BACKGROUND

The Pre-Crash Braking Simulation (References 1 through 4) was developed by Calspan Corporation as an investigation aid for assessing the role of vehicle braking performance in highway accidents. The format of the computer program and many of the individual subroutines are patterned closely after corresponding aspects of the CRASH2 program (Reference 5). Thus, the braking assessment algorithm may be viewed as a special adaptation of CRASH2.

The present review and evaluation has been focused on the adequacy of the developed computer program for the intended purpose. In particular, the analytical assumptions, selected approximation techniques and evidence requirements are reviewed to assess corresponding limitations on the validity and utility of results obtained with the computer program.

6.2 CONCLUSIONS AND RECOMMENDATIONS

6.2.1 Conclusions

6.2.1.1 The Pre-Crash Braking Simulation Program does not appear to serve a useful purpose.

The use of a plane-motion analytical approach to evaluate the effects of changes in braking performance bypasses the fundamental topic of brake balance and its effects on directional control under different conditions of tire-terrain friction and vehicle loading. The developed computer program makes use of increased braking "efficiency" to evaluate the needed performance "improvement" to avoid the given accident or to reduce its severity. However, the arbitrary "improvements," which are said to "not yet" include anti-lock braking, are not related to any identified design features in the vehicle brake system.

The extensive use of subjective data to establish the pre-crash coordinates and to estimate the achieved level of deceleration cannot be expected to yield a reliable estimate of the initial vehicle speed. A low estimate of the achieved level of deceleration will obviously indicate a greater potential for improvement than will a high estimate. Note that braking performance at a deceleration level less than that corresponding to locked wheels would always be "improved," in the context of the selected research approach, by an increased pedal force.

6.2.1.2 <u>The feasibility of performing useful calculations with data that can be obtained in relation to pre-crash events has not been established.</u>

A pilot study utilizing hand calculations and/or applications of an existing computer simulation of braking dynamics (e.g., Reference 7) should have preceded the development of a special computer program.

6.2.2 <u>Recommendation</u>

6.2.2.1 <u>A pilot program of investigations with increased emphasis on data related to pre-crash events (e.g., Reference 4) should be implemented.</u>

The collection of a representative body of pre-crash data will permit a realistic assessment of the extent of quantitative information that can be obtained by investigators. It will also permit the performance of preliminary analyses of patterns in the pre-crash vehicle behavior. Note that the results of experimental research of vehicle behavior under conditions of combined steering and braking indicate that significant differences exist within the current vehicle population (Reference 6). In particular, some vehicles "plow" tangentially while others "spin" when brakes are applied in a turn. Other patterns may also be found which can be related to specific brake-system design features.

If the extent of quantitative data is sufficient to justify reconstruction calculations and, further, if such calculations can yield useful information, hand calculations and/or application of an existing computer simulation of braking dynamics (e.g., Reference 7) would appear to be a logical first step. The results of a sample of hand calculations and/or computer simulations can be evaluated prior to a decision to automate a special calculation procedure for more extensive applications.

6.3 DISCUSSION OF RESULTS

The correlation of detailed control characteristics of vehicles with either collision occurrences or collision severity levels in actual highway accidents is an extremely complex task. The role of vehicle control properties tends to be obscured by effects of (1) the attention level, skill and judgment of the driver, (2) roadway surface and visibility conditions, and (3) the conditions of vehicle maintenance (e.g., tire pressures) and vehicle loading. Among the various aspects of vehicle control, brake system performance would appear to constitute the least difficult item for investigation, since tire marks produced by brake applications and/or reported observations of brake lights by witnesses are frequently available. However, a meaningful interpretation of related investigation results in terms of the role of brake system performance in accident occurrence must be based on a realistic assessment of both the level of deceleration achieved on the given surface and the corresponding effects on directional control.

The usefulness of the subject computer algorithm for assessment of braking performance is limited by a number of major factors.

6.3.1 Limitations Imposed by Analytical Approach and Performance Criterion

The computer algorithms described in References 1 through 4 are limited to plane motions and, therefore, they do not include effects produced by dynamic changes in the distribution of vehicle loading. Thus, the fundamental design problem of achieving an acceptable brake balance (i.e., front/rear distribution of brake torque) over a wide range of operating conditions is ignored in the developed procedure for assessment of "improved" vehicle braking. In fact, the term "improved braking performance," as used in References 1 through 4, appears to refer exclusively to a reduced stopping distance. Note that on page 3-9 of Reference 1, it is stated that "the single most important performance characteristic of braking systems in accident avoidance or injury reduction evaluation is stopping distance."

6.3.1.1 Stopping Distance Criterion of Performance

In Reference 1 (p. 3-35) it is stated that "in the range of pedal pressures that drivers are able to apply, just about all vehicles are able to lock their wheels." Thus, it follows that a deceleration level corresponding to the locked-wheel, or sliding, friction coefficient between the tires and any road surface can be achieved by most vehicles.

One anti-lock system (Mercedes-Benz) which "reduces stopping distance under all conditions" is discussed on page 2-26 of Reference 1. Other anti-lock systems (e.g., Chrysler Sure Brake) have "slightly higher" stopping distances on dry surfaces but "substantially reduced" stopping distances on wet surfaces. On the basis of the overall discussion of improvements in braking performance (Section 2.3.2 of Reference 1) and using the selected criterion for improvement, anti-lock is the only defined brake system design feature that can "improve" braking performance (i.e., reduce stopping distance) beyond that achievable with all wheels locked.

Yet it is stated on page 1 of Reference 2 that "anti-lock braking systems are not as yet simulated by the program." Therefore, it is not clear what the simulated "improvements" in brake performance (braking "efficiency" increases) within subroutine AVOID (p. 5 of Reference 3) are intended to represent in real-world brake systems.

6.3.1.2 Neglect of Directional Control Effects

On page 3-5 of Reference 1, it is stated, with regard to variable brake proportioning, that "although this approach tends to reduce braking efficiency, the advantages of retaining directional control over the complete operational range are considered to outweigh the loss of efficiency." This statement conflicts with the simplistic use of stopping distance as the only measure of braking performance.

Tha arbitrary limitation, in the computer program, of the braking of wheels of a steered vehicle to 50% of full lock-up (p. 36 of Reference 3), combined with the neglect of dynamic weight transfer from the rear to the front wheels in forward braking, precludes any meaningful results from the Pre-Crash Braking Simulation Program in relation to directional control while braking. Note that the limitation to 50% of full lock-up braking while steered effectively limits the corresponding reduction, by braking, of the maximum side-force capability to 13.4%, on the basis of a simple friction circle:

$$\sqrt{1.00 - (0.5)^2} = 0.866$$

In Table 6-5 on page 6-8 of Reference 1, "estimated benefits of improved braking" are presented with an indication that "this is exclusive of any design changes that would allow the operator to maintain the vehicle's directional stability in a panic braking situation."

6.3.2 Limitations Imposed by Evidence Requirements

6.3.2.1 Use of Subjective Data

The rationale for development of a pre-crash phase computer reconstruction program is presented on page 5-1 of Reference 1 wherein it is stated that "application of all these (hand calculation) techniques are very user dependent, and the results also rely, to some extent, on subjective interpretations by the user." The need for subjective interpretations is not, of course, altered by the use of a computer program. In fact, on page 4-24 of Reference 1, it is stated that "it is apparent from this listing of pre-crash data elements that many are subjective in nature or represent the subjective judgment of the investigator such that their accuracy is indeterminant and/or their interpretations are likely to lack consistency." On page 4-21, the developed reconstruction procedure is described as follows: "the reconstruction of the pre-crash phase is very much a process of combining the limited amount of quantitative evidence with the subjective information to obtain a 'best fit' solution for the data available."

6.3.2.2 Undefined Driver Behavior

The undefined effects of driver-vehicle interaction on the pre-crash phase of an accident constitute a major obstacle to correlation of brake system performance with accident involvement. This fact is acknowledged on page 3-18 of Reference 1 where it is stated that "since it is extremely difficult (if not impossible) to acquire valid information on the driver's braking behavior at the accident scene, driver-braking system interaction effects cannot be easily determined." Further, it is stated on page 3-16 that "independent of braking system performance parameters the effective employment of braking as the primary accident avoidance tactic depends on the timely application of brakes by the driver. If, because of inattentiveness or slow reaction, the driver delays application of the brakes in an emergency situation, the existence of superior performance may be meaningless."

6.3.3 Analytical Errors

6.3.3.1 Side Force Calculation

Among the many overstated criticisms of SMAC that are presented in Reference 8, the one item that is considered to have merit is related to the use of the tangent of the slip angle. The choice to use the slip angle in radians had been deliberate, in the interest of simplicity. Note that the tangent of that angle had been previously used in the HVOSM computer program (e.g., Reference 9). For the case of braking with a slip angle greater than 20°, significant errors were found to be introduced in the calculated side force of the tire by the direct use of the slip angle in radians.

The CRASH and SMAC programs were both modified in 1978 to make use of the tangent of the slip angle. However, in Reference 3 (1980), the slip angle in radians is again used directly in Subroutine TRAJ (p. 177, line no. 123, Labeled 55).

6.3.3.2 Calculation of ΔV

In Subroutine COLL, the speed change, ΔV, is calculated at the point of common velocity rather than at the center of gravity (Subroutine COLL, line nos. 215 through 219).

6.3.3.3 Other Possible Errors

A number of apparently typographical errors were found to exist in the four reports that were reviewed (e.g., p. 5-10 of Reference 1, p. 66 of Reference 3). However, in view of the conclusions reached in this evaluation, the equations were not all checked against the program listing (Reference 3).

6.4 REFERENCES

1. Jones, I. S., and Baum, A. S., "Accident Investigation Methodology to Assess the Role of Vehicle Braking Performance in Highway Safety. Volume I: Final Report," Calspan Report No. ZQ-5799-V-1, Contract No. DOT-HS-5-01230, April 1980.

2. Baum, A. S., and Lynch, J. P., "Accident Investigation Methodology to Assess the Role of Vehicle Braking Performance in Highway Safety. Volume II: User's Manual," Calspan Report No. ZQ-5799-V-1, Contract No. DOT-HS-5-01230, April 1980.

3. Baum, A. S., "Accident Investigation Methodology to Assess the Role of Vehicle Braking Performance in Highway Safety. Volume III: Programmer's Manual," Calspan Report No. ZQ-5779-V-1, Contract No. DOT-HS-5-01230, April 1980.

4. Hendricks, D. L., "Accident Investigation Methodology to Assess the Role of Vehicle Braking Performance in Highway Safety. Volume IV: Accident Investigator's Guide," Calspan Report No. ZQ-5779-V-1, Contract No. DOT-HS-5-01230, April 1980.

5. McHenry, R. R. and Lynch, J. P., "CRASH2 User's Manual," Interim Report, DOT-HS-5-01124, Calspan Report No. ZQ-5708-V-4, September 1976.

6. Rice, Roy S. and Davis, James A., "Vehicle Directional Control During Braking-in-a-Turn," Calspan Report No. ZP-5565-V, DOT-HS-4-00971, May 1975.

7. Piziali, R. A., "Dynamics of Automobiles During Brake Applications--Validation of a Computer Simulation," CAL Report No. VJ-2251-V-9, Contract No. CPR-11-3988, July 1971.

8. Warner, C. Y. and Perl, T. R., "The Accuracy and Usefulness of SMAC," Proceedings of the 22nd Stapp Conference, 1978.

9. McHenry, R. R., and DeLeys, N. J., "Vehicle Dynamics in Single Vehicle Accidents--Validation and Extensions of a Computer Program," CAL Report No. VJ-2251-V-3, Contract No. CPR-11-3988, December 1968.

SECTION 7. RECOMMENDATIONS AND CONCLUSION

This section presents some recommendations for continued improvements to the CRASH3 model and a conclusion on the present status of the program.

7.1 GENERAL RECOMMENDATIONS

All work on the CRASH3 would be simplified by taking steps to clarify and restructure the present program code. The present code is a product of several revisions over a period of many years, and it has accumulated awkward, unnecessary attributes which hamper debugging, analysis, and updating of the source code. Simple changes such as resequencing and improving the source code comments would be of value in this regard.

Another such change would be the removal of duplicate and unused variables from the CRASH3 code. It appears that an analogue to each major variable has been added along with each revision of or addition to the program. Some unused variables are known to be present. These conditions cause confusion as well as waste storage space.

In addition to unnecessary redefinition of variables, there are frequent duplications of code segments which could appear less often, but be executed more often, if the source code were streamlined and modularized.

The creation of an option to save CRASH3 input data in some on-line form would facilitate rapid, comprehensive testing of changes to the program code. One way to accomplish this would be to write out the common block storage areas to a disk file upon receipt of an appropriate command from the user. Later, the disk data file could be read in, thus placing the program directly in a position analogous to that situation which occurs at the commencement of the rerun option. The data files formed from the common blocks would be a very compact form of storage for the CRASH3 input data. This system would use the flexible and proven, but time consuming, QUIZ routine to accept data from the user, then enable the user to save and recall the case for future use. It might supplant the lengthy, rigid Batch option used in CRASH2 which has been eliminated in CRASH3. The Batch option is inflexible and contains many duplications of code found elsewhere in the CRASH2 program.

The development of such a "Save" option would facilitate the use of on-line data bases for CRASH3 testing and validation. Automatic testing could be performed quickly and easily, thus greatly reducing the cost of comprehensive testing of experimental program changes.

The FORTRAN language NAMELIST input-output facility could be used to provide more flexible diagnostic output with less clutter and confusion in the source code. NAMELIST input statements could be used to change intermediate values during execution of the program, a valuable feature for research purposes.

7.2 DAMAGE ANALYSIS

As might be expected in any empirically grounded model, the CRASH3 damage analysis could benefit from a larger and better collection of test data. Past damage tests should be selected, cataloged, and screened for greatest utility. Future damage measurements from staged collision tests should be monitored and validated carefully.

A consistent, explicit derivation of the A, B, and G coefficients should be established and documented. When A, B, and G can be derived from any well documented collision test, efforts can be made to develop new vehicle categories based exclusively on crush properties, rather than other measures such as vehicle wheelbase which are known to correlate poorly with crush stiffness in many instances. A well defined A, B, and G derivation could be automated and combined with data bases of damage test results to quickly and accurately refine the CRASH3 coefficients.

The correction factor for tangential forces in collisions with principle directions of force (PDOFs) not normal to the vehicle surface has been a frequent and significant source of inaccuracy in CRASH3 results. This problem is particularly prominent when the function $1 + \tan^2\theta$ grows large with large PDOF divergences from the normal position. Either the correction factor should be modified, or the aberrant cases selected for alternate treatment by the CRASH3 program.

7.3 SPINOUT ANALYSIS

The SPIN2 subroutine exhibits radically different responses depending on the path type specified by the answers to several YES-NO questions in the CRASH3 input routine. The results of SPIN2 should be compared by path type (e.g., "skidding with end of rotation point") to isolate weaknesses of the SPIN2 approach. Borderline cases would also provide insight into the operation of SPIN2 assumptions, if traced carefully through the analysis using alternate assumptions and comparing results.

The trajectory simulation routines could be tested by creating a special modification of CRASH3 which permits substitution of separation conditions by the user prior to the performance of the time history simulation. This modified program could be used with the measured separation conditions from the RICSAC cases to test the adequacy of the trajectory simulation equations of motion. If the trajectory simulation provided good results with actual separation conditions, attention could be focused on the error computation and adjustment procedures in subroutine USMAC. If the results were not good, the model of vehicle motion would be an identified target for revision.

The detailed analysis of several trajectory simulation runs, perhaps with additional, specially designed diagnostic printouts, would help to establish what happens, when, and where in those cases which evidence poor results.

Many poor trajectory simulation results are related to inputs of zero separation angular velocity from the SPIN2 subroutine, which produces this as an output value in all cases without skidding. The zero value is never changed by subroutine USMAC, since the angular velocity correction adjustment is a multiplier of the starting value. Some accommodation should be instituted for this situation, either in SPIN2 or USMAC or both subroutines.

The impact speeds computed by conservation of linear momentum might be improved by an allowance for a known zero impact velocity, characteristic of a vehicle known to be at rest at the time impact occurs.

7.4 PRINTOUT FORMAT

Input and output values are not distinguished clearly in the present CRASH3 printout. The identification of independent and dependent values should be obvious, and data from lookup tables should be clearly marked.

Some simple output results could be added to the abbreviated printout. Separation velocities and the trajectory simulation results would be good candidates for this change. This addition would make the short printout more useful as well as reduce the number of occasions on which the lengthy long form must be attended to by the user.

CRASH3 should report the user's answers to the yes or no questions which define the vehicle spinout path types. The answers to these questions are crucial to determining the type of analysis performed in each case. In the present printout, it is possible to extract or deduce the answers supplied to these questions, but not easily or in all cases. These items should be readily available in the printout.

Finally, there is duplication in the long form of the CRASH3 printout which could be eliminated. The impact position, collision conditions, and separation conditions sections of the printout are very repetitive. There seems to be no need to print summary results in the midst of a complete report, as is now the case. These alterations could significantly streamline the CRASH3 long form output.

7.5 CONCLUSIONS

The CRASH program is a complex, multivariate approach to a difficult problem of estimation. The model combines several analytical techniques to utilize a broad spectrum of input data and produce reasonably accurate results across a broad spectrum of vehicle collisions. In its present form, CRASH3 is able to produce figures which are "in the ballpark" for most well-documented accident cases.

The thrust of the present effort of CRASH3 maintenance and development has been to improve the results obtainable from the program along the lines of analysis which have been laid out by previous CRASH researchers.

Our conclusion is that there is more progress remaining to be made by further refinement of the basic methodologies which have been incorporated in the CRASH3 model. Each of the modes of analysis used in crash appears to be amenable to continued development. New empirical data can be collected and reduced to improve the empirical bases of the damage and spinout solutions. Augmented validity checking of the input data should yield better results from all components of the model. Logic can be developed to intercept special cases which do not fit standard CRASH3 assumptions and process them successfully.

All of these tasks will contribute to an increase in the degree of accuracy obtainable from CRASH3. They will also lay the groundwork for future analytical modifications to the model. It is our further conclusion that a comprehensive housecleaning, modularization, and restructuring of the CRASH3 program code, accompanied by improved documentation such as flow charts and a variable dictionary, would significantly reduce the time, cost, and difficulty of future development of CRASH3.

APPENDIX A

ILLUSTRATION OF CDC (VDI) SCANNING ROUTINE AS MODIFIED TO SCREEN J224MAR80 DAMAGE CODES

```
 ENTER TYPE OF CRASH RUN?
 (COMPLETE,ABBREVIATED,RERUN,PRINT,SMAC,OR END)
?ABBREVIATED


 WILL THE INPUT FOR THIS RUN BE IN METRIC FORM?
 (ANSWER YES OR NO)
?NO


  1. TITLE?
?TEST VDI (CDC) SCANNING ROUTINE


  2. CLASS/WEIGHTS?
?4 4


  3. CDC/PDOF # 1?
?X2FWEW2


 **** ILLEGAL CDC ****     CHECK COLUMN 1


  3. CDC/PDOF # 1?
?06BZ4Q3


 **** ILLEGAL CDC ****     CHECK COLUMN 5


  3. CDC/PDOF # 1?
?12FARK4


 **** ILLEGAL CDC ****     CHECK COLUMN 4


  3. CDC/PDOF # 1?
?12FDEWZ


 **** ILLEGAL CDC ****     CHECK COLUMN 7


  3. CDC/PDOF # 1?
?12FDEW3


  4. CDC/PDOF # 2?
?42FDEW3
```

```
  5. VEHICLE 1 AND VEHICLE 2 STIFFNESS CATEGORIES?
?$


  4. CDC/PDOF # 2?
?32FDEW3


  5. VEHICLE 1 AND VEHICLE 2 STIFFNESS CATEGORIES?
?$


  4. CDC/PDOF # 2?
?34FDEW3


 **** ILLEGAL CDC ****      CHECK COLUMN 2


  4. CDC/PDOF # 2?
?44FDEW3


  5. VEHICLE 1 AND VEHICLE 2 STIFFNESS CATEGORIES?
?6_$


  4. CDC/PDOF # 2?
?53FDEW3


 **** ILLEGAL CDC ****      CHECK COLUMN 2


  4. CDC/PDOF # 2?
?52FDEW3


  5. VEHICLE 1 AND VEHICLE 2 STIFFNESS CATEGORIES?
?
B-STOP
MRU=      2.072

#
```

APPENDIX B

RESULTS OF TASK 3

TABLE OF CONTENTS

1.0 INTRODUCTION

This is a report of the results of tasks 3A, 3B, and 3C of the CRASH2 maintenance project. We have assumed the reader's familiarity with the two CRASH models (CRASH2 and CRASH2A), their programs, their principal subroutines, and the final report, "Research Input for Computer Simulation of Automobile Collisions, (RICSAC), Volume IV: Staged Collision Reconstructions."

2.0 PURPOSE

The purpose of Task 3A was to activate the coding in CRASH2A which makes computations based on initial slip angles for either or both vehicles in a collision. Tasks 3B and 3C were designed to compare the results produced by CRASH2 and CRASH2A using identical input derived from the 12 RICSAC staged collisions.

3.0 PROCEDURES

Task 3A was accomplished by locating the statements relevant to the slip angle computation in the CRASH2A code, changing the statements, recompiling the source code, and executing several demonstration runs to illustrate the slip angle results. Tasks 3B and 3C were accomplished by executing the CRASH2A model using as input the data from the RICSAC test cases. The input was duplicated from the printouts in the appendix of the RICSAC final report. Task 3B consisted of CRASH2A runs without the trajectory simulation option; Task 3C included the trajectory simulation option. When running the trajectory simulation, all vehicle steer angles were set to zero and question 35 (terrain boundary) was answered "NO."

The RICSAC input to CRASH2A produced unsatisfactory output for many of the 12 test cases. Four of the cases failed input verification checks, three cases produced execution errors in subroutine VELCHK, and six cases produced execution errors in subroutine USMAC in the trajectory simulation (see Section 5.0).

To improve the utility of these results for comparison with those of CRASH2, several changes were made to the input data and to the CRASH2A program code. These alterations were conducted in consultation with the Contract Technical Manager, Thomas Noga, and are described in Section 5.0. To provide identical runs for comparison with the CRASH2A runs, all of the 12 RICSAC cases were rerun on CRASH2 after the input data modifications were completed. Also, it was necessary to supply CRASH2 runs with the trajectory simulation option, since the RICSAC tests do not include this data.

4.0 RESULTS

Table 1 displays the statements changed to activate the slip angle computation routines in CRASH2A. All changes occurred in the QUIZ subroutine. The printouts of several test runs will be included as an appendix in the final report.

Table 2 is a tabulation of results from CRASH2 and CRASH2A based on the SPIN2 momentum calculations. For Task 3B, the damage based results were identical for CRASH2 and CRASH2A.

Table 3 compares the results of the trajectory simulation option on CRASH2 and CRASH2A with the measured data from the RICSAC tests. Six cases are not available on CRASH2, due to execution errors in the program. These difficulties relate to the problem described in Task 4.F of the contract (see number 3 in Section 5.0).

Table 4 displays the results of the RICSAC data run on CRASH2A, and the results of subsequent modifications to the program code and input. Table 5 includes similar results obtained from the trajectory simulation runs.

TABLE 1

CRASH2A STATEMENT CHANGES WHICH ACTIVATE SLIP ANGLE COMPUTATIONS (TASK 3A)

(ALL CHANGES ARE IN SUBROUTINE QUIZ)

A) Line Number 3170, Statement Number 110

For inactive slip angles:

```
IF ((ICODE.GE.1).AND.(ICODE.LE.12)) GO TO 165
```

For active angles:

```
IF ((ICODE.GE.1).AND.(ICODE.LE.12)) GO TO 170
```

B) Line Number 8550, Statement Number 1500

For inactive slip angles:

```
GO TO (1950,1950,200),MENU
```

For active slip angles:

```
CONTINUE
```

C) Line Number 9990

For inactive slip angles:

```
IF (ICODE.EQ.-2) GO TO 1300
```

For active slip angles:

```
IF (ICODE.EQ.-2) GO TO 1850
```

Note: There are comments associated with the above lines of code which should be modified to preserve clarity when changes are made.

TABLE 2
CRASH RUNS FROM SPIN2 + (DAMAGE OR OBLIQUE), WITHOUT TRAJECTORY SIMULATION (TASK 3B)

RICSAC TEST NO.	ΔVS	MEASURED VALUES	CRASH2 VALUES	CRASH2A VALUES
1	V_1 imp	19.8	-9.7	-8.3
	tot	12.2	9.4	10.0
	long	-10.6	-2.8	-1.9
	lat	6.0	-9.0	-9.8
	V_2 imp	19.8	0.8	1.1
	tot	15.6	14.1	15.0
	long	-12.1	9.6	11.3
	lat	-9.8	-10.3	-9.8
			MRU=5.043	MRU=3.736
2	V_1 imp	31.5	32.8	31.7
	tot	19.6	22.0	23.2
	long	-16.5	-20.7	-21.6
	lat	10.5	7.7	8.6
	V_2 imp	31.5	35.6	36.3
	tot	--	33.0	34.8
	long	--	-25.4	-27.3
	lat	--	-21.1	-21.6
			MRU=4.998	MRU=4.879
6	V_1 imp	21.5	24.9	24.8
	tot	9.2	12.4	14.9
	long	-8.5	-12.2	-14.0
	lat	3.0	2.3	5.1
	V_2 imp	21.5	20.5	25.3
	tot	11.9	20.4	24.5
	long	-11.5	-13.3	-18.8
	lat	-3.2	-15.4	-15.7
			MRU=5.053	MRU=4.931
7	V_1 imp	29.1	26.2	25.9
	tot	12.0	11.6	26.8
	long	-11.5	-11.1	-23.2
	lat	-3.5	3.2	13.4
	V_2 imp	29.1	27.1	34.7
	tot	16.5	25.3	58.3
	long	-14.1	-18.2	-50.5
	lat	-8.5	-17.5	-29.2
			MRU=5.044	MRU=5.023
8	V_1 imp	20.75	19.0	16.7
	tot	15.3	11.1	12.6
	long	-12.7	-7.3	-6.9
	lat	8.6	8.4	10.5
	V_2 imp	20.75	25.0	25.7
	tot	10.7	10.6	12.0
	long	-7.2	-8.0	-10.0
	lat	-8.0	-6.9	-6.6
			MRU=5.074	MRU=3.853

TABLE 2
CRASH RUNS FROM SPIN2 + (DAMAGE OR OBLIQUE), WITHOUT TRAJECTORY SIMULATION (TASK 3B) (Continued)

RICSAC TEST NO.	ΔVS		MEASURED VALUES	CRASH2 VALUES	CRASH2A VALUES
9	V_1	imp	21.2	23.2	20.1
		tot	21.4	24.2	20.1
		long	-17.7	-22.1	-20.1
		lat	12.0	9.8	0.0
	V_2	imp	21.2	22.0	18.0
		tot	8.9	11.2	9.2
		long	-5.0	-4.5	0.0
		lat	-7.4	-10.2	-9.2
				MRU=5.032	MRU=3.774
10	V_1	imp	33.3	32.7	33.2
		tot	35.1	32.6	33.4
		long	-27.3	-26.5	-28.2
		lat	22.0	19.0	17.8
	V_2	imp	33.3	31.5	34.5
		tot	14.1	15.9	16.3
		long	-8.8	-9.3	-8.7
		lat	-11.0	-13.0	-13.8
				MRU=5.100	MRU=3.804
11	V_1	imp	20.4	17.2	22.1 fwd -1.7 lat
		tot	24.0	21.0	22.1
		long	-24.0	-21.0	-22.1
		lat	0.8	0.3	1.7
	V_2	imp	20.4	18.0	13.5 fwd -3.2 lat
		tot	15.7	13.2	13.9
		long	-15.6	-13.2	-13.5
		lat	2.0	0.2	3.2
				MRU=4.995	MRU=3.731
12	V_1	imp	31.5	19.8	19.9 fwd 1.2 lat
		tot	40.1	28.2	8.5
		long	-40.0	-28.1	-8.4
		lat	-2.2	-1.6	0.6
	V_2	imp	31.5	30.2	30.4 fwd 1.5 lat
		tot	26.4	20.0	11.6
		long	-26.0	-19.5	10.9
		lat	4.8	4.6	4.2
				MRU= 5.034	MRU=3.796
3	V_1	imp	21.2	15.2	19.8 fwd 0.2 lat
		tot	9.5	3.1	12.3
		long	-9.5	-3.1	12.3
		lat	-0.4	0.2	0.2
	V_2	imp	0.0	10.4	3.1 fwd -0.2 lat
		tot	15.8	5.4	15.0
		long	15.8	4.9	14.8
		lat	0.2	-2.3	-2.2
				MRU=5.105	MRU=3.733

TABLE 2
CRASH RUNS FROM SPIN2 + (DAMAGE OR OBLIQUE), WITHOUT TRAJECTORY SIMULATION (TASK 3B) (Continued)

RICSAC TEST NO.	ΔVS		MEASURED VALUES	CRASH2 VALUES	CRASH2A VALUES
4	V_1	imp	38.7	32.5	43.9 fwd 0.4 lat
		tot	18.7	10.9	26.5
		long	-18.7	-9.7	-26.3
		lat	0.4	4.9	3.6
	V_2	imp	0.0	2.2	-21.4 fwd 7.4 lat
		tot	22.2	15.5	41.4
		long	22.2	14.9	39.6
		lat	-2.8	-4.4	-12.0
				MRU=5.124	MRU=3.787
5	V_1	imp	39.7	33.6	29.3
		tot	16.3	7.9	0.0
		long	-16.3	-7.9	0.0
		lat	0.2	0.0	0.0
	V_2	imp	0.0	9.4	-33.7
		tot	25.1	15.9	23.2
		long	25.0	15.3	22.8
		lat	-1.8	-4.4	-4.1
				MRU=5.035	MRU=3.844

TABLE 3
CRASH RUNS WITH TRAJECTORY SIMULATION OPTION (TASK 3C)

RICSAC TEST NO.	VEHICLE NUMBER	TEST ITEM	MEASURED VALUES	CRASH2 VALUES	CRASH2A VALUES
1	1	SIMULATION		DID NOT CONVERGE	CONVERGED OK
		V IMPACT	19.8	14.7	0.6
		ΔV	12.2	9.7	11.0
	2	SIMULATION		TIMED OUT AT 10 SECONDS	DID NOT CONVERGE
		V IMPACT	19.8	20.6	-7.4
		ΔV	15.6	14.6	16.5
				MRU=10.369	MRU=21.326
2	1	SIMULATION		TIMED OUT AT 10 SECONDS	DID NOT CONVERGE
		V IMPACT	31.5	32.8	33.2
		ΔV	19.6	22.0	24.6
	2	SIMULATION		TIMED OUT AT 10 SECONDS	CONVERGED OK
		V IMPACT	31.5	35.6	39.5
		ΔV	--	33.0	36.9
				MRU=7.859	MRU=14.096
6	1	SIMULATION			DID NOT CONVERGE
		V IMPACT	21.5		24.0
		ΔV	9.2		14.2
	2	SIMULATION			CONVERGED OK
		V IMPACT	21.5		27.6
		ΔV	11.9		23.3
					MRU=21.189
7	1	SIMULATION			DID NOT CONVERGE
		V IMPACT	29.1		25.9
		ΔV	12.0		14.7
	2	SIMULATION			CONVERGED OK
		V IMPACT	29.1		40.8
		ΔV	16.5		32.0
					MRU=24.577
8	1	SIMULATION		DID NOT CONVERGE	DID NOT CONVERGE
		V IMPACT	20.75	11.4	19.3
		ΔV	15.3	11.5	18.1
	2	SIMULATION		TIMED OUT AT 10 SECONDS	DID NOT CONVERGE
		V IMPACT	20.75	25.5	21.8
		ΔV	10.7	11.0	17.2
				MRU=11.090	MRU=23.563
9	1	SIMULATION			DID NOT CONVERGE
		V IMPACT	21.2		39.1
		ΔV	21.4		39.7
	2	SIMULATION			TIMED OUT AT 10 SECONDS
		V IMPACT	21.2		19.9
		ΔV	8.9		18.3
					MRU=21.711

TABLE 3
CRASH RUNS WITH TRAJECTORY SIMULATION OPTION (TASK 3C) (Continued)

RICSAC TEST NO.	VEHICLE NUMBER	TEST ITEM	MEASURED VALUES	CRASH2 VALUES	CRASH2A VALUES
10	1	SIMULATION			DID NOT CONVERGE
		V IMPACT	33.3		26.7
		ΔV	35.1		33.4
	2	SIMULATION			TIMED OUT AT 10 SECONDS
		V IMPACT	33.3		34.5
		ΔV	14.1		16.3
					MRU=26.824
11	1	SIMULATION			DID NOT CONVERGE
		V IMPACT	20.4		15.6 fwd 4.7 lat
		ΔV	24.0		20.0
	2	SIMULATION			CONVERGED OK
		V IMPACT	20.4		17.3 fwd 1.0 lat
		ΔV	15.7		12.5
					MRU=14.218
12	1	SIMULATION		TIMED OUT AT 10 SECONDS	DID NOT CONVERGE
		V IMPACT	31.5	20.2	21.0
		ΔV	40.1	28.2	27.4
	2	SIMULATION		DID NOT CONVERGE	DID NOT CONVERGE
		V IMPACT	31.5	24.3	23.7
		ΔV	26.4	21.4	19.0
				MRU=9.346	MRU=18.318
3		SIMULATION		TIMED OUT AT 10 SECONDS	CONVERGED OK
		V IMPACT	21.2	15.2	19.8 fwd 0.2 lat
		ΔV	9.5	3.1	12.3
	2	SIMULATION		TIMED OUT AT 10 SECONDS	CONVERGED OK
		V IMPACT	0.0	10.4	3.1 fwd -0.2 lat
		ΔV	15.8	5.4	15.0
				MRU=7.637	MRU=3.833
4	1	SIMULATION		TIMED OUT AT 10 SECONDS	TIMED OUT AT 10 SECONDS
		V IMPACT	38.7	32.5	43.9 fwd 0.4 lat
		ΔV	18.7	10.9	26.5
	2	SIMULATION		TIMED OUT AT 10 SECONDS	TIMED OUT AT 10 SECONDS
		V IMPACT	0.0	2.2	21.4 fwd 7.4 lat
		ΔV	22.2	15.5	41.4
				MRU=7.913	MRU=13.386
5	1	SIMULATION			TIMED OUT AT 10 SECONDS
		V IMPACT	39.7		55.0
		ΔV	16.3		29.2
	2	SIMULATION			DID NOT CONVERGE
		V IMPACT	0.0		-34.6 fwd 14.6 lat
		ΔV	25.1		57.2
					MRU=25.236

TABLE 4
CRASH2A RUNS WITHOUT TRAJECTORY SIMULATION (TASK 3B)

RICSAC TEST NUMBER	FIRST ATTEMPT RICSAC INPUT DUPLICATED	SECOND ATTEMPT PDOF ANGLES ADDED	THIRD ATTEMPT SPIN2 STATEMENT CHANGED
1	OK		
2	INCOMPATIBLE PDOF'S	VELCHK ERROR	OK
6	INCOMPATIBLE PDOF'S	VELCHK ERROR	OK
7	INCOMPATIBLE PDOF'S	VELCHK ERROR	OK
8	OK		
9	OK		
10	OK		
11	OK		
12	OK		
3	OK		
4	INCOMPATIBLE PDOF'S	OK	
5	OK		

TABLE 5

CRASH2A RUNS WITH TRAJECTORY SIMULATION (TASK 3C)

RICSAC TEST NUMBER	FIRST ATTEMPT RICSAC INPUT DUPLICATED	SECOND ATTEMPT PDOF ANGLES ADDED	THIRD ATTEMPT SPIN2 STATEMENT CHANGED	FOURTH ATTEMPT NULL ROTATION WHEN NO SKIDDING
1	OK			
2	INCOMPATIBLE PDOF'S	VELCHK ERROR	USMAC ERROR	OK
6	INCOMPATIBLE PDOF'S	VELCHK ERROR	USMAC ERROR	OK
7	INCOMPATIBLE PDOF'S	VELCHK ERROR	USMAC ERROR	OK
8	OK			
9	USMAC ERROR			OK
10	OK			
11	USMAC ERROR			OK
12	OK			
3	OK			
4	INCOMPATIBLE PDOF'S	OK		
5	USMAC ERROR			OK

5.0 DETAILS OF PROBLEMS ENCOUNTERED

1. Principal Direction of Force (PDOF) Incompatibility - The equations for both the CRASH2 and CRASH2A models assume that the PDOF angles are 180° apart for the two vehicles in a collision. CRASH2 does not verify this condition; however, CRASH2A does so in the following manner. The impact heading angles (question 7) are combined with the PDOF angles from questions 3 and 4 and tested for a 180° ± 15° offset. The PDOF angles are entered specifically by the user or are derived from the clock direction included in the VDI. If the data fails the offset test, CRASH2A returns to question 3 (VDI number 1) after displaying a warning message.

   Four of the test runs from the RICSAC final report fail the PDOF compatibility check in CRASH2A. These are cases 2, 6, 7, and 5. In each case, no PDOF angles were entered by the user, and the VDI-based angles were not 180° apart.

   To correct this problem, acceptable PDOF angles were added to the test case input data from the RICSAC report. The angles selected were those listed as direction angles in the Measured Damaged Dimensions section of the summary of physical evidence displayed for each test case. In each case, these angles produced the requisite 180° offset and passed the CRASH2A input verification routine. Subsequently, these "new" PDOF angles were added to the input data used for the final reruns of CRASH2, to preserve comparability of the test conditions.

2. SPIN2 Coding Error - Three of the RICSAC test cases produced execution errors in subroutine VELCHK. These cases, numbers 2, 6, and 7, involved no skidding of vehicle number 1. In subroutine VELCHK, three lines past statement number 290, a division by zero occurs if US1 and VS1 are zero. US1 and VS1 are the separation velocities of vehicle number 1, and are not expected to be zero.

   The program logic which produced zero values for US1 and VS1 can be traced as follows. Beginning in subroutine START2, S1D is assigned a value based on the length of the path travelled between the end of rotation and rest positions. S1D denotes the residual linear velocity from the non-skidding portion of the vehicle path.

Subroutine START2 calls subroutine SPIN2 to determine the separation velocity for each vehicle. If there is no skidding, end of rotation and impact positions have been set equal by subroutine QUIZ. In subroutine SPIN2, the skidding path length is derived from the distance from impact to end of rotation, and is zero if these points are coincident, which occurs in cases without skidding. (See the line after statement number 220 in subroutine SPIN2 for the skidding path length computation.) Statement number 345 in subroutine SPIN2 jumps to statement number 665 if the skidding flag is not set, as occurs in cases without skidding. Statement number 665 changes the value of S1D to zero. This value, the residual linear velocity, was derived from the non-skidding path length in subroutine START2. Statement number 670 assigns a zero value to SSDOT, the resultant separation velocity, when S1 and S1D are zero. This sequence of steps produces separation velocities of zero for the non-skidding vehicle, and leads to the division by zero in subroutine VELCHK.

It was judged that statement number 665 in subroutine SPIN2, which resets S1D to zero in the CRASH2A code, was in error in these cases. Statement number 665 was changed to a "Continue" statement to correct the problem. The division by zero in VELCHK ceased when this change was made.

3. Trajectory Simulation Error - There is a coding problem in the USMAC subroutine of both the CRASH2 and the CRASH2A programs. This problem is similar but not exactly the same as that described in Task 4.F of the contract. When activated by the user in response to question number 31 (CRASH2) or 32 (CRASH2A), subroutine USMAC performs a time history simulation of the spinout for each vehicle in a collision. Subroutine USMAC accepts the separation velocities computer by subroutine SPIN2 and uses TRAJ, RKING, and DAUX subroutines to simulate the spinout trajectory. If the simulated trajectory does not end with the vehicle at rest within a specified time limit, subroutine USMAC sets a flag and returns control to the calling program. This condition is denoted by "timing out" in the CRASH output displays.

   If a simulated trajectory ends within the time limit allowed, several errors are computed by comparing the simulated results with the measured results entered by the user. The five error terms are:

E(1) = rest position distance
E(2) = end of rotation position distance
E(3) = rest position heading angle
E(4) = end of rotation heading angle
E(5) = point on curve distance

Each error is computed as a ratio of the simulated and measured values. This can lead to problems when the divisor is zero. In the present versions of CRASH2 and CRASH2A divisions by zero occur which lead to fatal execution errors.

In both CRASH programs, there is a sequence of statements at the conclusion of the QUIZ routine which set the end of rotation point to the same location as the impact point when the user has specified no skidding. In these cases, the impact to end of rotation distance and the heading angle change are both zero. In the CRASH2 program these zero values cause divisions by zero when the error terms listed above are computed.

The CRASH2A program includes some protection against division by zero in some, but not all, cases. If rotation has been specified, but no skidding, the variable TEMP5 will be set to a zero value and then used as a divisor in the statements two lines beyond statement numbers 460 and 510. TEMP5 is the difference in heading between impact and end of rotation, which is zero in cases without skidding (since subroutine QUIZ has set the impact and end of rotation points equal).

It was noted that this problem could arise whenever the difference in heading between impact and end of rotation is closed to zero, regardless of the distance involved. Three different cases are possible in the computation of the ratio between the predicted and the measured heading change between impact and end of rotation.

1. The predicted difference could be close to zero, in which case the ratio would be close to zero.

2. The measured difference could be close to zero, in which case the ratio would be very large and likely to overflow.

3. Both the measured and predicted values could be small, in which case the ratio value would be unpredictable.

Case 2 is causing the problems in the present RICSAC runs, but the other possibilities should be allowed for in resolving this problem.

Several solutions to this problem have been proposed. CRASH2 could be improved to the degree present in CRASH2A by duplicating the CRASH2A code with appropriate changes; however, this still leaves the CRASH2A weakness.

Two approaches have been outlined to the CRASH2A problem at this point. One is to further refine the error computation routine to handle the three problem cases described above. This could be accomplished in a manner similar to that in which other computations in the neighboring pieces of code are protected.

Another approach is to study the situation which allows the flag for rotation to be set when the skidding flag is not. There is some evidence in the program that rotation is considered to be a type of skidding, and consequently should not occur unless skidding occurs. The elimination of rotation when there is no skidding does not preclude heading changes, according to the program logic. In the RICSAC test cases which caused execution errors on CRASH2A, elimination of the rotation flag allowed each case to run successfully.

Further study of the variable definitions and program logic is necessary to indicate the best resolution of this difficulty.

4. SPIN2 Zero Values - On some of the RICSAC runs executed on CRASH 2A, the impact speeds, speeds along the line between the centers of gravity, and velocity changes based on linear momentum were output as zero for one or both vehicles in the collision. This problem appeared in cases 3, 5, 11, and 12. The problem may be in one of two places, either the subroutine PRINT or the program logic invoked when the velocity vectors of the two vehicles are offset less than 10° at impact. Further examination of these occurrences is recommended; although they did not prevent execution of the test runs, some results may be questionable.

6.0 CONCLUSIONS

It is apparent from the results of these tests that significant differences exist between the results of the CRASH2 and CRASH2A programs executed with identical input. The coding problems that have affected the proposed comparisons should be resolved to facilitate the evaluation of each program for accuracy of results. The need to resolve these difficulties is especially important to permit a comparison of the trajectory simulation between these two versions of the CRASH model.

APPENDIX C

RESULTS OF TASK 4

INTRODUCTION

This report summarizes the results of Task 4 of the CRASH2 program maintenance contract. The purpose of Task 4 was to identify, verify, and correct programming errors in the CRASH2 code.

Task 4 encompassed nine possible errors in the CRASH2 code and an analogy to one of the nine which might appear in the CRASH2A revision of the CRASH2 program. Several additional errors were located and corrected during the performance of Task 4. These findings are included in this report.

Throughout this report basic familiarity with the CRASH2 and CRASH2A programs has been assumed on the reader's part. In addition, it would be very helpful to refer to a listing of the program code in conjunction with this document.

Several interactive runs of the CRASH2 and CRASH2A programs are included with this report. These runs were selected to display the problems considered in Task 4 and to demonstrate the corrections which were applied.

Within Task 4 are Tasks A-I. The order of presentation of the Tasks (A-I) in this report has been altered to conform to the logical flow of the CRASH2 program. Tasks B, C, D, and G concern problems with the user interrogation and input processing QUIZ subroutine. They are listed first. Tasks A and I involve subroutine DAMAGE, which is the first analysis performed by the program on the user supplied input. These results are next in this text. The spinout analysis problems described in Tasks E and H follow the problems with subroutine DAMAGE. Tasks 4.F.i and 4.F.ii concern problems with subroutine USMAC, a principal part of the trajectory simulation, which is optionally invoked by the user to verify and improve the results of the spinout analysis.

B. Subroutine QUIZ, Statement 3305, IF IFLAG(2).EQ.2; (IFLAG cannot equal 2).

Statement 3305 in subroutine QUIZ is presently coded:

```
3305 IF (IFLAG(2).EQ.2) GO TO 3315
```

The variable IFLAG(2) signals whether an End of Rotation (EOR) point has been included in the CRASH2 input data. The possible values of IFLAG(2) are 1, indicating that an EOR point has been included in the data; and 0, indicating that no EOR point has been entered.

IFLAG(2) is initially set equal to one, by a statement six lines past statement 104. Statement 3050 sets IFLAG(2) equal to zero if question 19 (Skidding Stop Before Rest?) is answered 'NO'. A statement six lines past statement 3160 sets IFLAG(2) equal to one if acceptable EOR coordinates have been entered in response to question 20 (End of Skidding Coordinates?). Hence, at statement 3305, IFLAG(2) will equal one or zero, but not two.

Statement 3305 should be corrected to read:

```
3305 IF (IFLAG(2).EQ.1) GO TO 3315
```

This coding will branch to the appropriate version of question 22 (Point on Curve?) depending on the presence of an EOR point as signaled by IFLAG(2).

Statement 3300 is also in error in the present CRASH2 program. The current version reads:

```
3300 GO TO (3305,3320,3320),ICODE
```

This computed GO TO statement should be indexed by the variable MENU rather than ICODE. This statement is designed to select the short or long form of question 22 depending on the type of CRASH2 run which is in progress (full, abbreviated, or rerun). It should be corrected to read:

```
3300 GO TO (3305,3320,3320),MENU
```

C. Subroutine QUIZ, Statement following statement 5650, GO TO (5600,5600,666),MENU; (the first 5600 should be 5700).

The statement following statement 5650 reads:

```
GO TO (5600,5600,666),MENU
```

This statement is executed following a default response to question 45 (Side Damage Depth #2). The present coding will cause question 45 to be presented repeatedly when a default response occurs.

Instead, the QUIZ subroutine should branch to question 46 if a default response occurs. Question 46 begins at statement 5700. Therefore, the corrected statement following statement 5650 should be:

```
GO TO (5700,5700,666),MENU
```

The statements three and four lines after statement 5630 both read:

```
IF (ICODE.EQ.2) GO TO 5660
```

These lines are identical and sequential, hence one should be removed.

D. Subroutine QUIZ, Statement 6011; Question 49 of the abbreviated input should involve Vehicle #2.

As currently coded, the short form of question 49 prints this:

```
49. END DAMAGE MIDPOINT OFFSET #2
```

The current text does indicate that Vehicle #2 is involved. This question is entirely analogous to the same question asked concerning Vehicle #1 which is coded at statement 5911. Thus, it does not appear that any changes are required.

G. Subroutine QUIZ, the statement following statement 6480 is a GO TO 6500; this should be a GO TO 6400 to allow a correction to an "outlandish response."

The statement following statement 6480 is now coded:

GO TO 6500

Statement 6480 prints an error message when the direction of force angle entered in response to question 53 (Principal Force Angle #1?) exceeds 360°. After the error message is displayed, the program as coded skips to the next question, which begins at statement 6500.

Instead, the program should repeat the presentation of question 53 to permit a correction by the user. To accomplish this, the statement "GO TO 6500" should be changed to read:

GO TO 6400

A. Subroutine DAMAGE--"CDC only" run cannot be performed if Vehicle #1 alone has CDC only.

A test run was made using the input data from RICSAC test number 8. For Vehicle #1, only a VDI was supplied. For Vehicle #2, detailed damage dimensions were supplied. This input produced no problems, and the result is included as Task 4A, Example 1 (see Appendix).

A second run was made to test the reverse situation, with complete damage dimensions for Vehicle #1 and a VDI only for Vehicle #2. It was impossible to run this test successfully, because of the problem described in Task 4C above. The error in the statement after 5650 repeats question 45 when a default response is entered, thus it is impossible to proceed past question 45 without supplying some data. The effect of this problem is illustrated by Example 2 (see Appendix).

A third attempt was made after correcting the problem in Task 4C, with VDI only supplied for Vehicle #2. This run was successful, and is included as Example 3 (see Appendix). An examination of the DAMAGE subroutine has revealed no other restraints on similar runs of this type, with complete information on one vehicle and a VDI only for the other. In all cases, subroutine DAMAGE constructs default values for all required variables based on the user supplied vehicle class and VDI. Then, any additional data that is available is used in place of the default values. Each vehicle is analyzed identically within subroutine DAMAGE; thus, there is no apparent reason that sufficient data for one vehicle would not be sufficient for another.

I. Subroutine DAMAGE--The value for D can change from one rerun to the next; investigate the cause of this phenomenon.

The input data from MRA test #1 was used for a series of runs to investigate this phenomenon. The results are displayed as Example 4 (see Appendix). (Example 4 is also a test run for Task 4H.) One run was successful, with detailed damage dimensions for both vehicles. Then a rerun was made, to check for changes in the value of D. Only the title was changed for the rerun. The values for D for Vehicle #1 and #2 are the same in the original results as in the rerun (D_1 = -25.5", D_2 = -23.4"). A second rerun with another title again produced the same D values.

An analysis of subroutine DAMAGE suggests no apparent alteration of D values from one rerun to the next. The user entered value for the moment arm D is stored as the variable DD(I) for each vehicle. Subroutine DAMAGE accesses DD in common area CRASH, where it has been stored by the input subroutine QUIZ. Subroutine DAMAGE uses another variable D(I) to contain the adjusted value of D used in the damage-based calculations.

At the third line after statement 10 in subroutine DAMAGE, D(I) is set equal to zero. D(I) is assigned a value based on the VDI at one of the following statement numbers: 1230, 1240, 1280, 1285, 1290, 1295, 1510, 1525, 1550, 1555, 1560, 1565. The assignment of D(I) depends on the type of collision damage present, according to the entered VDI.

At statement 1931, D(I) is set equal to the value DD(I), if DD(I) has been entered by the user. This replaces the VDI-based D value with the measured D value stored in DD(I), if the measured value is available.

At statement 2000, the value of D(I) is adjusted by a factor derived from the other damage dimensions. The value of DD(I) is not affected. In fact, the user entered value DD(I) is not assigned a value by any statement in the DAMAGE subroutine. The variable D(I) is reassigned by subroutine DAMAGE, but it is reset before a rerun occurs. Thus, it is difficult to identify a source of changes in the value of D from one rerun to the next.

One possible source of confusion on this subject lies in the output display of the CRASH2 program. In the detailed, full printout of results, a value labeled "D" is listed in the summary of damage data section. The source of this value is the variable D(I), which is the adjusted value of D used in the damage calculations. The user entered value of D, which is stored as DD(I), is not printed out, though it is stored from one rerun to the next.

In the CRASH2A revision of the CRASH2 program, this ambiguity has been reduced by printing both DD(I) and D(I) for each vehicle. In the CRASH2A printout DD(I) is labeled D and D(I) is labeled D'.

H. CRASH2 produces a spinout error message on Calspan test MRA #1; test NHTSA overlay to discover the reason for the spinout error detected.

The input data for MRA #1 was obtained from a printout of several CRASH3 runs titled 'CRASH3 Checkout Runs With Diagnostics' provided by Mr. Thomas Noga of NHTSA. MRA #1 is the first test run in this series.

When this data was entered into the CRASH2 program, the program executed successfully with no spinout error messages.

At Mr. Noga's suggestion the same data was run on the CRASH2A revision of the CRASH2 program. Again, no spinout errors appeared.

The results of test MRA #1 on three versions of the CRASH program are summarized in Table 1. The test run on CRASH2 is included in this report as Example 4 (see Appendix). The test run on CRASH2A is included as Example 5 (see Appendix). The CRASH3 results were obtained from the printout described above.

TABLE 1

RESULTS OF MRA TEST #1

			CRASH2	CRASH2A	CRASH3
Vehicle #1	Impact	fwd.	37.1	39.1	37.6
		lat.	--	2.2	-0.2
	Δ V	tot.	36.9	37.6	38.7
		long.	-36.6	-37.5	-38.4
		lat.	4.7	2.3	4.9
Vehicle #2	Impact	fwd.	37.3	38.1	35.6
		lat.	--	0.0	1.5
	Δ V	tot.	28.6	29.3	30.2
		long.	-28.6	-29.3	-29.9
		lat.	2.2	1.7	3.8

Notes: All speeds are miles per hour.
CRASH3 results are from CRASH3 checkout runs provided by NHTSA.

Notice in Table 1 that the results from the three versions of CRASH produced very similar results with this data. At this time, the actual measured data is not available for inclusion in this report.

E. <u>Calculation of path length in cases with curved path but no rotation specified; the path length calculated presently may be grossly overestimated</u>.

The total path length travelled by a vehicle in the CRASH2 model is the sum of the skidding path length and the non-skidding path length. The non-skidding path length is computed in subroutine START. The skidding path length is calculated in subroutine SPIN2.

In subroutine START the variables DIST1 and DIST2 are used to store the non-skidding path length for Vehicles #1 and #2. If no End of Rotation (EOR) point has been entered for a vehicle, DIST1 or DIST2 is set to zero. If an EOR point is present for a vehicle, as signaled by the variable IFLAG(I) being equal to one, DIST1 or DIST2 is set equal to the straight-line distance from the EOR point to the rest point. This assignment occurs at statement numbers 1020 and 1040, for Vehicles #1 and #2 respectively.

The skidding path length is calculated in subroutine SPIN2. If there is a curved path, as indicated by the flag JCV, the path length is computed by a series of statements beginning four statements past statement 525. In these cases, with path curvature, the path length is determined to be the arc length along a circle passing through the impact and end of rotation positions of a vehicle. The center of this circle is computed in subroutine START. The variable S1 is used to store the arc length from impact to end of rotation. S1 is then used as the skidding distance in subsequent SPIN2 calculations.

The presence of rotation, as signaled by the variable IRT(I) for either vehicle, has no effect on the path length computation. However, the presence of an entirely non-skidding trajectory for either vehicle will lead to an erroneous path length computation as detailed next.

If there is no skidding, the end of rotation point is set equal to the impact point at the conclusion of subroutine QUIZ. When a curved path is specified, the arc from impact to end of rotation is zero, since these points are identical. Subroutine SPIN2 also evaluates the arc from the impact point to the point on the curved path which has been entered by the user. SPIN2 compares the arc of the EOR point with the arc to the point on the curve. This test occurs at the statement immediately preceeding statement 530.

If the arc to the point on the curve is smaller than the arc to the EOR point, it is assumed that the point on the curve lies between the impact and EOR points, as it should. In this case the value assigned to S1 based on the computed arc length from impact to EOR is passed for further spinout analyses.

If the arc to the point on the curve is bigger than the arc to the EOR, the program assumes that the arc to EOR has been measured around the circle in the wrong direction. In this case, the value of S1 is reset to the length of the entire circumference of the circle on which the trajectory lies, minus the original S1 value. This substitution measures S1 in the opposite direction around the circle, in effect.

If the arc from impact to EOR is zero, as happens in all cases without skidding, the arc to the point on the curve will invariably exceed it. Then, the original value of S1 will be replaced with the entire circumference of the circular path minus the initial S1 value of zero. This leads to the replacement of a correct value of zero for the skidding path length with a much larger, erroneous number.

To correct this problem, the following statement should be inserted three lines after statement 525:

```
    IF (JSKID(JVEH).EQ.0) GO TO 200
```

This coding change will prevent an incorrect curved, skidding path length from being computed when in fact the skidding path length is zero since no skidding occurred. The coincidence of the impact and EOR points will result in the proper value of zero for S1 being assigned at the statement immediately following statement 200.

The analysis of this problem brought to light the fact that there is no provision for a curved path during the non-skidding portion of a vehicle's trajectory in the current CRASH2 program. Investigation of the CRASH2A program shows that this procedure is unchanged. This defect will be dealt with in forthcoming work on the CRASH programs.

F.i <u>Subroutine USMAC; if question set 11, 14, 16 and/or 18, 21, 23 are answered with a "No," a simulation run is impossible. The "end-of-rotation point" and the "point on the curve" are set to the coordinates of the point of separation. The computation of the error terms E(2) and E(5) in USMAC then involve a fatal divide by zero error.</u>

F.ii <u>Check CRASH2A for the same error</u>.

This problem has been discussed in Part 3 of Section 5 of the report on Task 3 of this contract, under the paragraph titled "Trajectory Simulation Error." The problem boils down to several divisions by zero which can occur in subroutine USMAC when the impact and end of rotation points are coincident, a situation that occurs in all cases without skidding.

Divisions by zero cause FORTRAN runtime execution errors and immediate termination of the CRASH2A program. CRASH2A has some protection against this problem. This protection was extended and completed by the introduction of twelve additional statements in subroutine USMAC. These additions are displayed in Figure 1, which is a section of the modified code from subroutine USMAC in CRASH2A.

Example 6 (see Appendix) is a test run using the modified version of subroutine USMAC. This case will not run on the unmodified CRASH2A program free of errors, but executes successfully on the modified version.

The protection against undefined divisions now available in subroutine USMAC of CRASH2A was added to the USMAC subroutine of the CRASH2 program to prevent similar problems. The new coding, displayed in Figure 2, was added to CRASH2 by replacing the appropriate section of subroutine USMAC in the CRASH2 code. It is identical to the CRASH2A code with the exception of several statement numbers which have been altered to conform to CRASH2 requirements.

Figure 3 is a second piece of code taken from CRASH2A and inserted into subroutine USMAC of CRASH2. This code precludes undefined arc-tangent function evaluations when the end of rotation and impact points are identical.

Example 7 (see Appendix) is a test run on the modified version of CRASH2. This case fails to run due to execution errors on the present version of CRASH2.

FIGURE 1. CODING CHANGES IN SUBROUTINE USMAC, CRASH2A TRAJECTORY SIMULATION

```
C
C   SIMULATION HAS FINISHED.
C   CALCULATE THE FIVE MEASURES OF PREDICTION ERROR
C   IF NO CURVED PATH, BYPASS E(5) COMPUTATION
C
  410 TEMP1 = SQRT((XRP-XRPP)*(XRP-XRPP) + (YRP-YRPP)*(YRP-YRPP))
      TEMP2 = SQRT((XRP-XSP)*(XRP-XSP) + (YRP-YSP)*(YRP-YSP))
      E(1) = TEMP1/TEMP2
      IF   (IFLAG(JVEH) .EQ. 0)    GO TO 415
      TEMP1 = SQRT((X1P-X1PP)*(X1P-X1PP) + (Y1P-Y1PP)*(Y1P-Y1PP))
      TEMP2 = SQRT((X1P-XSP)*(X1P-XSP) + (Y1P-YSP)*(Y1P-YSP))
      IF   ((TEMP2) .LT. 10.0)    GO TO 420
      E(2) = TEMP1/TEMP2
      GO TO 430
  415 E(2) = 0.
      GO TO 430
  420 E(2) = 0.0083*TEMP1
  430 IF   (IABS(IRT(JVEH)) .GT. 0)    GO TO 440
      E(3) = 2.865*(PSISP-PSIRPP)
      E(4) = 2.865*(PSISP-PSI1PP)
      GO TO 550
  440 IF   (IRT(JVEH) .GE. 0)    GO TO 450
      GO TO 500
  450 TEMP3 = PSIRP - PSISP
      IF   (TEMP3 .GE. 0.)    GO TO 460
      TEMP3 = TEMP3 + 6.2832
  460 TEMP3 = TEMP3 + 6.2832*FLOAT(JIND(JVEH))
      TEMP4 = PSIRPP - PSISP
      IF   ((ABS(TEMP3) .LT. .035) .AND. (ABS(TEMP4) .LT. .035))
     *     GO TO 465
      GO TO 470
  465 E(3) = 0.0
      GO TO 475
  470 IF(ABS(TEMP3).LT..035) GO TO 542
      E(3) = 1.0 - (TEMP4/TEMP3)
  475 IF   (IFLAG(JVEH) .EQ. 0)    GO TO 485
      TEMP5 = PSI1P - PSISP
      IF   (TEMP5 .GE. 0.)    GO TO 480
      TEMP5 = TEMP5 + 6.2832
  480 TEMP5 = TEMP5 + 6.2832*FLOAT(JIND(JVEH))
      TEMP6 = PSI1PP - PSISP
      GO TO 490
  485 E(4) = 0.
      GO TO 550
  490 IF(ABS(TEMP5).LT..035) GO TO 544
      E(4) = 1.0 - (TEMP6/TEMP5)
      GO TO 550
  500 TEMP3 = PSISP - PSIRP
      IF   (TEMP3 .GE. 0.)    GO TO 510
      TEMP3 = TEMP3 + 6.2832
  510 TEMP3 = TEMP3 + 6.2832*FLOAT(JIND(JVEH))
      TEMP4 = PSISP - PSIRPP
      IF   ((ABS(TEMP3) .LT. .035) .AND. (ABS(TEMP4) .LT. .035))
     *     GO TO 515
      GO TO 520
  515 E(3) = 0.0
      GO TO 525
  520 IF(ABS(TEMP3).LT..035) GO TO 542
      E(3) = 1.0 - (TEMP4/TEMP3)
  525 IF   (IFLAG(JVEH) .EQ. 0)    GO TO 535
      TEMP5 = PSISP - PSI1P
```

```
      IF    (TEMP5 .GE. 0.)   GO TO 530
      TEMP5 = TEMP5 + 6.2832
  530 TEMP5 = TEMP5 + 6.2832*FLOAT(JIND(JVEH))
      TEMP6 = PSISP - PSI1PP
      GO TO 540
  535 E(4) = 0.
      GO TO 550
  540 IF(ABS(TEMP5).LT..035) GO TO 544
      E(4) = 1.0 - (TEMP6/TEMP5)
      GO TO 550
  542 E(3)=2.865*TEMP4
      IF(IRT(JVEH).GE.0) GO TO 475
      GO TO 525
  544 E(4)=2.865*TEMP6
  550 IF    (JCURV(JVEH) .EQ. 0)    GO TO 560
      TEMP1 = SQRT((X2P-XSP)*(X2P-XSP) + (Y2P-YSP)*(Y2P-YSP))
      E(5) = DISTM/TEMP1
      GO TO 570
  560 E(5) = 0.0
C
C
#
```

FIGURE 2. TRAJECTORY SIMULATION CODE FROM SUBROUTINE USMAC IN CRASH2A, AS MODIFIED AND INSERTED IN CRASH2

```
C
C   SIMULATION HAS FINISHED.
C   CALCULATE THE FIVE MEASURES OF PREDICTION ERROR
C   IF NO CURVED PATH, BYPASS E(5) COMPUTATION
C
  410 TEMP1 = SQRT((XRP-XRPP)*(XRP-XRPP) + (YRP-YRPP)*(YRP-YRPP))
      TEMP2 = SQRT((XRP-XSP)*(XRP-XSP) + (YRP-YSP)*(YRP-YSP))
      E(1) = TEMP1/TEMP2
      IF  (IFLAG(JVEH) .EQ. 0)   GO TO 415
      TEMP1 = SQRT((X1P-X1PP)*(X1P-X1PP) + (Y1P-Y1PP)*(Y1P-Y1PP))
      TEMP2 = SQRT((X1P-XSP)*(X1P-XSP) + (Y1P-YSP)*(Y1P-YSP))
      IF  ((TEMP2) .LT. 10.0)   GO TO 420
      E(2) = TEMP1/TEMP2
      GO TO 430
  415 E(2) = 0.
      GO TO 430
  420 E(2) = 0.0083*TEMP1
  430 IF   (IABS(IRT(JVEH)) .GT. 0)   GO TO 440
      E(3) = 2.865*(PSISP-PSIRPP)
      E(4) = 2.865*(PSISP-PSI1PP)
      GO TO 550
  440 IF   (IRT(JVEH) .GE. 0)   GO TO 449
      GO TO 499
  449 TEMP3 = PSIRP - PSISP
      IF   (TEMP3 .GE. 0.)   GO TO 460
      TEMP3 = TEMP3 + 6.2832
  460 TEMP3   TEMP3 + 6.2832*FLOAT(JIND(JVEH))
      TEMP4 = PSIRPP - PSISP
      IF   ((ABS(TEMP3) .LT. .035) .AND. (ABS(TEMP4) .LT. .035))
     *      GO TO 465
      GO TO 470
  465 E(3) = 0.0
      GO TO 475
  470 IF(ABS(TEMP3).LT..035) GO TO 542
      E(3) = 1.0 - (TEMP4/TEMP3)
  475 IF   (IFLAG(JVEH) .EQ. 0)   GO TO 485
      TEMP5 = PSI1P - PSISP
      IF   (TEMP5 .GE. 0.)   GO TO 480
      TEMP5 = TEMP5 + 6.2832
  480 TEMP5 = TEMP5 + 6.2832*FLOAT(JIND(JVEH))
      TEMP6 = PSI1PP - PSISP
      GO TO 490
  485 E(4) = 0.
      GO TO 550
  490 IF(ABS(TEMP5).LT..035) GO TO 544
      E(4) = 1.0 - (TEMP6/TEMP5)
      GO TO 550
  499 TEMP3 = PSISP - PSIRP
      IF   (TEMP3 .GE. 0.)   GO TO 510
      TEMP3 = TEMP3 + 6.2832
  510 TEMP3 = TEMP3 + 6.2832*FLOAT(JIND(JVEH))
      TEMP4 = PSISP - PSIRPP
      IF   ((ABS(TEMP3) .LT. .035) .AND. (ABS(TEMP4) .LT. .035))
     *      GO TO 515
      GO TO 520
  515 E(3) = 0.0
      GO TO 525
  520 IF(ABS(TEMP3).LT..035) GO TO 542
      E(3) = 1.0 - (TEMP4/TEMP3)
  525 IF   (IFLAG(JVEH) .EQ. 0)   GO TO 535
      TEMP5 = PSISP - PSI1P
```

```
      IF (TEMP5 .GE. 0.)   GO TO 530
      TEMP5 = TEMP5 + 6.2832
  530 TEMP5 = TEMP5 + 6.2832*FLOAT(JIND(JVEH))
      TEMP6 = PSI[illegible] - PSI1PP
      GO TO 540
  545 E(4) = 0
      GO TO 5[illegible]
  540 IF(ABS(TEMP5).[illegible].035) GO TO 544
      E(4 [illegible] 0 [illegible] (TEMP6/TEMP5)
      GO [illegible] 550
  5[illegible] E(3) 2.865*TEMP4
      IF [illegible] (VEH).GE.0) GO TO 475
      GO TO 525
  544 E(4) 2.865*TEMP6
  550 IF [illegible] (CURV(JVEH) .EQ. 0)   GO TO 560
      TEMP[illegible] SQRT((X2P-XSP)*(X2P-XSP) + (Y2P-YSP)*(Y2P-YSP))
      E(5) [illegible] DISTM/TEMP1
      GOTO [illegible]0
  560 E(5) [illegible].0
```

FIGURE 3. ADDITIONAL CRASH2A TRAJECTORY SIMULATION CODE ADDED TO CRASH2 TO PREVENT ERRORS

```
61870C
61880C   CALCULATE THE AZIMUTH ERROR FOR THE END-OF-ROTATION POSITION
61890C
61900  820 IF   (IFLAG(JVEH) .EQ. 0)    GO TO 825
61902      IF (ABS(X1P-XSP) .LT. .001) GAM1 = ATAN2((Y1P-YSP),.001)
61904      IF (ABS(X1P-XSP) .GE. .001) GAM1 = ATAN2((Y1P-YSP),(X1P-XSP))
61906      IF (ABS(X1PP-XSP) .LT. .001) GAM1P = ATAN2((Y1PP-YSP),.001)
61908      IF (ABS(X1PP-XSP) .GE. .001) GAM1P = ATAN2((Y1PP-YSP),(X1PP-XSP)
61910      TEMP1 = GAM1 - GAM1P
61912      IF   ((TEMP1 .LT. 1.57) .AND. (TEMP1 .GT. -1.57))  E2G = TEMP1
61914      IF   (TEMP1 .GE. 1.57)   E2G = TEMP1 - 6.283
61916      IF   (TEMP1 .LE. -1.57)   E2G = TEMP1 + 6.283
61918      GO TO 830
61920  825 E2G = 0.
61922C
61924C   CALCULATE THE RANGE ERROR FOR THE END-OF-ROTATION POSITION
61926C
61928  830 IF   (IFLAG(JVEH) .EQ. 0)    GO TO 835
61930      L1 = SQRT((X1P-XSP)*(X1P-XSP) + (Y1P-YSP)*(Y1P-YSP))
61932      L1P = SQRT((X1PP-XSP)*(X1PP-XSP) + (Y1PP-YSP)*(Y1PP-YSP))
61934      E2L = (L1-L1P)/L1P
61936      IF   (E2L .LE. -.99)   E2L = -.99
61938      GO TO 2040
61940  835 E2L = 0.
62030C
#
```

APPENDIX

EXAMPLE 1. VDI ONLY FOR VEHICLE #1

```
          RUN CRA2LOM.C0162

CRA2LOM  12:47    JUN 09,'80


 ENTER TYPE OF CRASH RUN?
 (COMPLETE,ABBREVIATED,RERUN,PRINT,BATCH,SMAC,OR END)
?A


 WILL THE INPUT FOR THIS RUN BE IN METRIC FORM?
 (ANSWER YES OR NO)
?NO

  1. TITLE?
?RICSAC #8 WITH VDI ONLY FOR VEHICLE 1

  2. SIZE CATEGORIES?
?I I

  3. VDI, #1
?12FDEW1

  4. VDI, #2
?03RYEW2

  5. ACTUAL WEIGHTS? (Y OR N)
?Y

  6. WEIGHT #1
?

  7. WEIGHT #2
?4710

  8. REST & IMPACT? (Y OR N)
?N

 37. DAMAGE DIMENSIONS? (Y OR N)
?Y
```

41. END DAMAGE WIDTH #1
?

42. END DAMAGE DEPTH #1
?

43. END DAMAGE MIDPOINT OFFSET #1
?

44. SIDE DAMAGE WIDTH #2
?84.5

45. SIDE DAMAGE DEPTH #2
?6.2 8.3 9.2 5.9 4.4 .8

46. SIDE DAMAGE MIDPOINT OFFSET #2
?15.

50. RATIO OF DAMAGE EXTENTS? #1
?

52. FORCE DIRECTIONS (Y OR N)
?N

THANK YOU VERY MUCH

SUMMARY OF CRASH RESULTS

RICSAC #8 WITH VDI ONLY FOR VEHICLE 1

	VEHICLE # 1	VEHICLE # 2
SPEED CHANGE (DAMAGE ONLY)	11.3 MPH .0 DEG	10.2 MPH 90.0 DEG
ENERGY DISSIPATED BY DAMAGE	18862.0 FT-LB	15610.4 FT-LB

ENTER TYPE OF CRASH RUN?
(COMPLETE,ABBREVIATED,RERUN,PRINT,BATCH,SMAC,OR END)
?P

SUMMARY OF CRASH RESULTS

RICSAC #8 WITH VDI ONLY FOR VEHICLE 1

```
                          VEHICLE # 1
*************************************************************************
*            *                                   *                      *
*            *        SPEED  CHANGE              *                      *
*IMPACT SPEED*             MPH                   *                      *
*            *                                   *                      *
*    MPH     *************************************        BASIS         *
*            *          *           *            *          OF          *
*            *  TOTAL   *   LONG.   *  LATERAL   *       RESULTS        *
*            *          *           *            *                      *
*************************************************************************
*            *          *           *            *                      *
*            *          *           *            *                      *
*            *          *           *            *SPINOUT TRAJECTORIES*
                                                 *AND CONSERVATION OF *
```

IMPACT SPEED MPH	SPEED CHANGE MPH TOTAL	LONG.	LATERAL	BASIS OF RESULTS
				LINEAR MOMENTUM
				SPINOUT TRAJECTORIES AND DAMAGE
	11.3	-11.3	.0	DAMAGE DATA ONLY

VEHICLE # 2

IMPACT SPEED MPH	SPEED CHANGE MPH TOTAL	LONG.	LATERAL	BASIS OF RESULTS
				SPINOUT TRAJECTORIES AND CONSERVATION OF LINEAR MOMENTUM
				SPINOUT TRAJECTORIES AND DAMAGE
	10.2	-.0	-10.2	DAMAGE DATA ONLY

SUMMARY OF DAMAGE DATA (* INDICATES DEFAULT VALUE)

	VEHICLE # 1		VEHICLE # 2	
TYPE	INTERMEDIATE		INTERMEDIATE	
WEIGHT	4247.0 LBS.	*	4710.0 LBS.	
VDI	12FDEW1		03RYEW2	
L	77.0 IN.	*	84.5 IN.	
C1	6.2 IN.	*	6.2 IN.	
C2	6.2 IN.	*	8.3 IN.	
C3	6.2 IN.	*	9.2 IN.	
C4	6.2 IN.	*	5.9 IN.	
C5	0.0 IN.	*	4.4 IN.	
C6	0.0 IN.	*	.8 IN.	
D	0.0 IN.	*	7.8 IN.	
RHO	1.00	*	1.00	*
ANG	360.0 DEG.	*	90.0 DEG.	*

DIMENSIONS AND INERTIAL PROPERTIES

A1 = 54.7 INCHES   A2 = 54.7 INCHES

```
B1      =     59.2 INCHES             B2      =     59.2 INCHES
TR1     =     61.8 INCHES             TR2     =     61.8 INCHES
I1      =  41113.6 LB-SEC**2-IN       I2      =  45600.7 LB-SEC**2-IN
M1      =   10.990 LB-SEC**2/IN       M2      =   12.189 LB-SEC**2/IN
XF1     =     98.8 INCHES             XF2     =     98.8 INCHES
XR1     =   -114.0 INCHES             XR2     =   -114.0 INCHES
YS1     =     38.5 INCHES             YS2     =     38.5 INCHES

ENTER TYPE OF CRASH RUN?
(COMPLETE,ABBREVIATED,RERUN,PRINT,BATCH,SMAC,OR END)
?E

                    CRASH PROGRAM COMPLETED.
  STOP

MRU=      4.438

#
```

EXAMPLE 2. PROBLEM WITH DEFAULT DAMAGE DATA FOR VEHICLE #2

```
 RUN CRA2LDM


CRA2LDM   13:19    JUN 09,'80



 ENTER TYPE OF CRASH RUN?
 (COMPLETE,ABBREVIATED,RERUN,PRINT,BATCH,SMAC,OR END)
?A


 WILL THE INPUT FOR THIS RUN BE IN METRIC FORM?
 (ANSWER YES OR NO)
?NO

   1. TITLE?
?RICSAC #8 WITH VDI ONLY FOR VEHICLE #2

   2. SIZE CATEGORIES?
?I I

   3. VDI, #1
?12FDEW1

   4. VDI, #2
?03RYEW2

   5. ACTUAL WEIGHTS? (Y OR N)
?Y

   6. WEIGHT #1
?4479

   7. WEIGHT #2
?

   8. REST & IMPACT? (Y OR N)
?N

  37. DAMAGE DIMENSIONS? (Y OR N)
?Y

  41. END DAMAGE WIDTH #1
?73

  42. END DAMAGE DEPTH #1
?2.7 3.6

  43. END DAMAGE MIDPOINT OFFSET #1
?0

  44. SIDE DAMAGE WIDTH #2
?

  45. SIDE DAMAGE DEPTH #2
?

  45. SIDE DAMAGE DEPTH #2
?

  45. SIDE DAMAGE DEPTH #2
?
B-S
```

EXAMPLE 3. VDI ONLY FOR VEHICLE #2

```
RNH:CRA2LDM

MRU=      0.001

#CNHE CRA2LDM

 CRA2LDM        1  (PU,R )        6D   NUL    06/09/80    06/09/80    06/09/80
                                              13:45 HRS   13:45 HRS   13:46 HRS

#RNH CRA2LDM


 ENTER TYPE OF CRASH RUN?
 (COMPLETE,ABBREVIATED,RERUN,PRINT,BATCH,SMAC,OR END)
?A


 WILL THE INPUT FOR THIS RUN BE IN METRIC FORM?
 (ANSWER YES OR NO)
?NO

   1. TITLE?
?RICSAC #8 WITH VDI ONLY FOR VEHICLE #2

   2. SIZE CATEGORIES?
?I I

   3. VDI, #1
?12FDEW1

   4. VDI, #2
?03RYEW2

   5. ACTUAL WEIGHTS? (Y OR N)
?Y

   6. WEIGHT #1
?4479

   7. WEIGHT #2
?

   8. REST & IMPACT? (Y OR N)
?N

  37. DAMAGE DIMENSIONS? (Y OR N)
?Y

  41. END DAMAGE WIDTH #1
?73

  42. END DAMAGE DEPTH #1
?2.7 3.6

  43. END DAMAGE MIDPOINT OFFSET #1
?0

  44. SIDE DAMAGE WIDTH #2
?
```



```
  45. SIDE DAMAGE DEPTH #2
?
```

46. SIDE DAMAGE MIDPOINT OFFSET #2
?

52. FORCE DIRECTIONS (Y OR N)
?N

THANK YOU VERY MUCH

SUMMARY OF CRASH RESULTS

RICSAC #8 WITH VDI ONLY FOR VEHICLE #2

	VEHICLE # 1	VEHICLE # 2
SPEED CHANGE (DAMAGE ONLY)	6.5 MPH	6.8 MPH
	.0 DEG	90.0 DEG
ENERGY DISSIPATED BY DAMAGE	9324.0 FT-LB	10510.4 FT-LB

ENTER TYPE OF CRASH RUN?
(COMPLETE,ABBREVIATED,RERUN,PRINT,BATCH,SMAC,OR END)
?P

SUMMARY OF CRASH RESULTS

RICSAC #8 WITH VDI ONLY FOR VEHICLE #2

VEHICLE # 1

IMPACT SPEED MPH	SPEED CHANGE MPH TOTAL	SPEED CHANGE MPH LONG.	SPEED CHANGE MPH LATERAL	BASIS OF RESULTS
				SPINOUT TRAJECTORIES AND CONSERVATION OF LINEAR MOMENTUM
				SPINOUT TRAJECTORIES AND DAMAGE
	6.5	-6.5	.0	DAMAGE DATA ONLY

VEHICLE # 2

****

```
*            *                                             *                     *
*            *        SPEED  CHANGE                        *                     *
*IMPACT SPEED*                   MPH                       *                     *
*            *                                             *       BASIS         *
*    MPH     *******************************                *        OF           *
*            *          *           *                      *      RESULTS        *
*            *   TOTAL  *    LONG.  *  LATERAL             *                     *
*            *          *           *                      *                     *
**********************************************************************************
*            *          *           *                      *                     *
*            *          *           *                      *SPINOUT TRAJECTORIES*
*            *          *           *                      *AND CONSERVATION OF *
*            *          *           *                      *LINEAR MOMENTUM     *
*            *          *           *                      *                     *
**********************************************************************************
*            *          *           *                      *                     *
*            *          *           *                      *SPINOUT TRAJECTORIES*
*            *          *           *                      *        AND         *
*            *          *           *                      *       DAMAGE       *
*            *          *           *                      *                     *
**********************************************************************************
*            *          *           *                      *                     *
*            *     6.8*        -.0*          -6.8*  DAMAGE DATA ONLY  *
*            *          *           *                      *                     *
**********************************************************************************
```

SUMMARY OF DAMAGE DATA (* INDICATES DEFAULT VALUE)

VEHICLE # 1			VEHICLE # 2		
TYPE----------	INTERMEDIATE		TYPE----------	INTERMEDIATE	
WEIGHT--------	4479.0 LBS.		WEIGHT--------	4247.0 LBS.	*
VDI-----------	12FDEW1		VDI-----------	03RYEW2	
L-------------	73.0 IN.		L-------------	98.8 IN.	*
C1------------	2.7 IN.		C1------------	0.0 IN.	*
C2------------	3.6 IN.		C2------------	4.0 IN.	*
C3------------	0.0 IN.		C3------------	4.0 IN.	*
C4------------	0.0 IN.		C4------------	8.0 IN.	*
C5------------	0.0 IN.		C5------------	0.0 IN.	*
C6------------	0.0 IN.		C6------------	0.0 IN.	*
D-------------	1.7 IN.		D-------------	62.2 IN.	*
RHO-----------	1.00	*	RHO-----------	1.00	*
ANG-----------	360.0 DEG.	*	ANG-----------	90.0 DEG.	*

DIMENSIONS AND INERTIAL PROPERTIES

A1	= 54.7 INCHES	A2	= 54.7 INCHES
B1	= 59.2 INCHES	B2	= 59.2 INCHES
TR1	= 61.8 INCHES	TR2	= 61.8 INCHES
I1	= 43364.2 LB-SEC**2-IN	I2	= 41113.6 LB-SEC**2-IN
M1	= 11.592 LB-SEC**2/IN	M2	= 10.990 LB-SEC**2/IN
XF1	= 98.8 INCHES	XF2	= 98.8 INCHES
XR1	= -114.0 INCHES	XR2	= -114.0 INCHES
YS1	= 38.5 INCHES	YS2	= 38.5 INCHES

```
ENTER TYPE OF CRASH RUN?
(COMPLETE,ABBREVIATED,RERUN,PRINT,BATCH,SMAC,OR END)
?END

                    CRASH PROGRAM COMPLETED.
  STOP
```

MRU=   4.899

#

EXAMPLE 4. MRA TEST #1 ON CRASH2 PLUS RERUNS TO TEST FOR CHANGES IN D

```
 RUN CRA2LDN_M


CRA2LDM  13:57    JUN 09,'80



 ENTER TYPE OF CRASH RUN?
 (COMPLETE,ABBREVIATED,RERUN,PRINT,BATCH,SMAC,OR END)
?A


 WILL THE INPUT FOR THIS RUN BE IN METRIC FORM?
 (ANSWER YES OR NO)
?NO

  1. TITLE?
?MRA #1 TO CHECK FOR SPINOUT ERROR

  2. SIZE CATEGORIES?
?I I

  3. VDI, #1
?12FYEW4

  4. VDI, #2
?12FYEW5

  5. ACTUAL WEIGHTS? (Y OR N)
?Y

  6. WEIGHT #1
?3080

  7. WEIGHT #2
?3950

  8. REST & IMPACT? (Y OR N)
?Y

  9. REST COORDINATES?
?-7.3 4.2 -25. .7 -2.5 162.48

 10. IMPACT COORDINATES?
```

?-8.4 1. 0. 8.4 -1. 180.

11. SKIDDING OF # 1? (Y OR N)
?Y

12. SKIDDING STOP BEFORE REST? (Y OR N)
?N

14. CURVED PATH? (Y OR N)
?N

16. ROTATION DIRECTION #1?
?CCW

17. MORE THAN 360 DEG? (Y OR N)
?NO

18. SKIDDING OF # 2? (Y OR N)
?Y

19. SKIDDING STOP BEFORE REST? (Y OR N)
?N

21. CURVED PATH? (Y OR N)
?N

23. ROTATION DIRECTION # 2?
?CCW

24. MORE THAN 360 DEG? (Y OR N)
?N

25. TIRE-GROUND FRICTION?
?.5

26. ROLLING RESISTANCE OPTION?(1 OR 2)
?1

27. ROLL. RESISTANCES, INDIV. WHEELS # 1
?0 0_1 0 0

28. ROLL. RESISTANCES, INDIV. WHEELS # 2
?0 1 0 0

31. TRAJECTORY SIMULATION? (Y OR N)
?NO

37. DAMAGE DIMENSIONS? (Y OR N)
?Y

41. END DAMAGE WIDTH #1
?34

42. END DAMAGE DEPTH #1
?46.5 35.8 25.2 14.5

43. END DAMAGE MIDPOINT OFFSET #1
?-22.5

47. END DAMAGE WIDTH #2
?45

48. END DAMAGE DEPTH #2
?57 49.8 42.7 35.5

```
 49. END DAMAGE MIDPOINT OFFSET #2
?-22

 52. FORCE DIRECTIONS (Y OR N)
?

 **** SYNTAX ERROR ****

 52. FORCE DIRECTIONS (Y OR N)
?N


                    THANK YOU VERY MUCH


                    SUMMARY OF CRASH RESULTS

 MRA #1 TO CHECK FOR SPINOUT ERROR

                                          VEHICLE # 1    VEHICLE # 2

 SPEED CHANGE (TRAJ. + DAMAGE)              36.9 MPH       28.6 MPH
                                            -7.3 DEG       -4.4 DEG
 SPEED CHANGE (DAMAGE ONLY)                 36.6 MPH       28.6 MPH
                                              .0 DEG         .0 DEG
 IMPACT SPEED                               37.1 MPH       37.3 MPH
 ENERGY DISSIPATED BY DAMAGE           93522.8 FT-LB 191574.4 FT-LB
 SPEED ALONG LINE THRU CGS                  36.9 MPH       37.1 MPH
 SPEED ORTHOG. TO CG LINE                    4.4 MPH        4.4 MPH
 CLOSING VELOCITY                           73.9 MPH


 ENTER TYPE OF CRASH RUN?
 (COMPLETE,ABBREVIATED,RERUN,PRINT,BATCH,SMAC,OR END)
?P


                    SUMMARY OF CRASH RESULTS

 MRA #1 TO CHECK FOR SPINOUT ERROR


                      VEHICLE # 1
*****************************************************************
*            *                            *                     *
*            *        SPEED  CHANGE       *                     *
*IMPACT SPEED*            MPH             *                     *
*            *                            *        BASIS        *
*    MPH     ******************************          OF         *
*            *         *         *        *       RESULTS       *
*            *  TOTAL  *  LONG.  * LATERAL *                    *
*            *         *         *        *                     *
*****************************************************************
*            *         *         *        *                     *
*            *         *         *        *SPINOUT TRAJECTORIES*
*            *         *         *        *AND CONSERVATION OF *
*            *         *         *        *LINEAR MOMENTUM      *
*            *         *         *        *                     *
*****************************************************************
*            *         *         *        *                     *
*            *         *         *        *SPINOUT TRAJECTORIES*
*        37.1*     36.9*   -36.6*      4.7*         AND         *
*            *         *                  *       DAMAGE        *
```

		36.6	-36.6	.0	DAMAGE DATA ONLY

VEHICLE # 2

IMPACT SPEED MPH	SPEED CHANGE MPH TOTAL	LONG.	LATERAL	BASIS OF RESULTS
				SPINOUT TRAJECTORIES AND CONSERVATION OF LINEAR MOMENTUM
37.3	28.6	-28.6	2.2	SPINOUT TRAJECTORIES AND DAMAGE
	28.6	-28.6	.0	DAMAGE DATA ONLY

SCENE INFORMATION

	VEHICLE # 1		VEHICLE # 2	
IMPACT X-POSITION	-8.40	FT.	8.40	FT.
IMPACT Y-POSITION	1.00	FT.	-1.00	FT.
IMPACT HEADING ANGLE	0.00	DEG.	179.98	DEG.
REST X-POSITION	-7.30	FT.	.70	FT.
REST Y-POSITION	4.20	FT.	-2.50	FT.
REST HEADING ANGLE	-25.00	DEG.	162.46	DEG.
DIRECTION OF ROTATION	CCW		CCW	
AMOUNT OF ROTATION	<360		<360	

COLLISION CONDITIONS

VEHICLE # 1

XC10'	=	-8.4 FT.
YC10'	=	1.0 FT.
PSI10	=	0.0 DEGREES
PSI1D0	=	0.0 DEG/SEC
U10	=	37.1 MPH
V10	=	0.0 MPH

VEHICLE # 2

XC20'	=	8.4 FT.
YC20'	=	-1.0 FT.
PSI20	=	180.0 DEGREES
PSI2D0	=	0.0 DEG/SEC
U20	=	37.3 MPH
V20	=	0.0 MPH

SEPARATION CONDITIONS

XCS1	=	-8.4 FT.	XCS2	=	8.4 FT.
YCS1	=	1.0 FT.	YCS2	=	-1.0 FT.
PSIS1	=	0.0 DEG	PSIS2	=	180.0 DEG
US1	=	.5 MPH	US2	=	8.8 MPH
VS1	=	4.7 MPH	VS2	=	2.2 MPH
PSISD1	=	-53.3 DEG/SEC	PSISD2	=	-23.6 DEG/SEC

RELATIVE VELOCITY DATA

	VEHICLE # 1	VEHICLE # 2
SPEED CHANGE (TRAJ. + DAMAGE)	36.9 MPH	28.6 MPH
	-7.3 DEG	-4.4 DEG
SPEED CHANGE (DAMAGE ONLY)	36.6 MPH	28.6 MPH
	.0 DEG	.0 DEG
IMPACT SPEED	37.1 MPH	37.3 MPH
ENERGY DISSIPATED BY DAMAGE	93522.8 FT-LB	191574.4 FT-LB
SPEED ALONG LINE THRU CGS	36.9 MPH	37.1 MPH
SPEED ORTHOG. TO CG LINE	4.4 MPH	4.4 MPH
CLOSING VELOCITY	73.9 MPH	

SUMMARY OF DAMAGE DATA (* INDICATES DEFAULT VALUE)

VEHICLE # 1			VEHICLE # 2		
TYPE----------	INTERMEDIATE		TYPE----------	INTERMEDIATE	
WEIGHT--------	3080.0 LBS.		WEIGHT--------	3950.0 LBS.	
VDI-----------	12FYEW4		VDI-----------	12FYEW5	
L-------------	34.0 IN.		L-------------	35.0 IN.	
C1------------	46.5 IN.		C1------------	57.0 IN.	
C2------------	35.8 IN.		C2------------	49.8 IN.	
C3------------	25.2 IN.		C3------------	42.7 IN.	
C4------------	14.5 IN.		C4------------	35.5 IN.	
C5------------	0.0 IN.		C5------------	0.0 IN.	
C6------------	0.0 IN.		C6------------	0.0 IN.	
D-------------	-25.5 IN.		D-------------	-23.4 IN.	
RHO-----------	1.00	*	RHO-----------	1.00	*
ANG-----------	360.0 DEG.	*	ANG-----------	360.0 DEG.	*

DIMENSIONS AND INERTIAL PROPERTIES

A1	=	54.7 INCHES	A2	=	54.7 INCHES
B1	=	59.2 INCHES	B2	=	59.2 INCHES
TR1	=	61.8 INCHES	TR2	=	61.8 INCHES
I1	=	29819.6 LB-SEC**2-IN	I2	=	38242.6 LB-SEC**2-IN
M1	=	7.971 LB-SEC**2/IN	M2	=	10.223 LB-SEC**2/IN
XF1	=	98.8 INCHES	XF2	=	98.8 INCHES
XR1	=	-114.0 INCHES	XR2	=	-114.0 INCHES
YS1	=	38.5 INCHES	YS2	=	38.5 INCHES

ROLLING RESISTANCE

VEHICLE # 1		VEHICLE # 2	
RF------------	0.00	RF------------	0.00
LF------------	1.00	LF------------	1.00
RR------------	0.00	RR------------	0.00
LR------------	0.00	LR------------	0.00

MU------------ .50

```
 ENTER TYPE OF CRASH RUN?
 (COMPLETE,ABBREVIATED,RERUN,PRINT,BATCH,SMAC,OR END)
?RERUN


 WILL THE INPUT FOR THIS RUN BE IN METRIC FORM?
 (ANSWER YES OR NO)
?NO


 QUESTION NUMBERS?
?1

   1. TITLE?
?A NEW TITLE TO CHECK FOR CHANGES IN D VALUES

                      THANK YOU VERY MUCH


                      SUMMARY OF CRASH RESULTS

 A NEW TITLE TO CHECK FOR CHANGES IN D VALUES

                                     VEHICLE # 1     VEHICLE # 2

 SPEED CHANGE (TRAJ. + DAMAGE)          36.9 MPH        28.6 MPH
                                        -7.3 DEG        -4.4 DEG
 SPEED CHANGE (DAMAGE ONLY)             36.6 MPH        28.6 MPH
                                          .0 DEG          .0 DEG
 IMPACT SPEED                           37.1 MPH        37.3 MPH
 ENERGY DISSIPATED BY DAMAGE         93522.8 FT-LB 191574.4 FT-LB
 SPEED ALONG LINE THRU CGS              36.9 MPH        37.1 MPH
 SPEED ORTHOG. TO CG LINE                4.4 MPH         4.4 MPH
 CLOSING VELOCITY                       73.9 MPH


 ENTER TYPE OF CRASH RUN?
 (COMPLETE,ABBREVIATED,RERUN,PRINT,BATCH,SMAC,OR END)
?P


                      SUMMARY OF CRASH RESULTS

 A NEW TITLE TO CHECK FOR CHANGES IN D VALUES


                         VEHICLE # 1
 *************************************************************
 *           *                               *               *
 *           *       SPEED   CHANGE          *               *
 *IMPACT SPEED*             MPH              *               *
 *           *                               *     BASIS     *
 *    MPH    *********************************      OF       *
 *           *         *         *           *    RESULTS    *
 *           *  TOTAL  *  LONG.  * LATERAL   *               *
 *           *         *         *           *               *
 *************************************************************
 *           *         *         *           *               *
 *           *         *         *           *SPINOUT TRAJECTORIES*
 *           *         *         *           *AND CONSERVATION OF *
```

				LINEAR MOMENTUM
37.1	36.9	-36.6	4.7	SPINOUT TRAJECTORIES AND DAMAGE
	36.6	-36.6	.0	DAMAGE DATA ONLY

VEHICLE # 2

IMPACT SPEED MPH	SPEED CHANGE MPH TOTAL	LONG.	LATERAL	BASIS OF RESULTS
				SPINOUT TRAJECTORIES AND CONSERVATION OF LINEAR MOMENTUM
37.3	28.6	-28.6	2.2	SPINOUT TRAJECTORIES AND DAMAGE
	28.6	-28.6	.0	DAMAGE DATA ONLY

SCENE INFORMATION

	VEHICLE # 1		VEHICLE # 2	
IMPACT X-POSITION	-8.40	FT.	8.40	FT.
IMPACT Y-POSITION	1.00	FT.	-1.00	FT.
IMPACT HEADING ANGLE	0.00	DEG.	179.98	DEG.
REST X-POSITION	-7.30	FT.	.70	FT.
REST Y-POSITION	4.20	FT.	-2.50	FT.
REST HEADING ANGLE	-25.00	DEG.	162.46	DEG.
DIRECTION OF ROTATION	CCW		CCW	
AMOUNT OF ROTATION	<360		<360	

COLLISION CONDITIONS

VEHICLE # 1			VEHICLE # 2		
XC10'	=	-8.4 FT.	XC20'	=	8.4 FT.
YC10'	=	1.0 FT.	YC20'	=	-1.0 FT.

PSI10	=	0.0 DEGREES	PSI20	=	180.0 DEGREES
PSI1D0	=	0.0 DEG/SEC	PSI2D0	=	0.0 DEG/SEC
U10	=	37.1 MPH	U20	=	37.3 MPH
V10	=	0.0 MPH	V20	=	0.0 MPH

SEPARATION CONDITIONS

XCS1	=	-8.4 FT.	XCS2	=	8.4 FT.
YCS1	=	1.0 FT.	YCS2	=	-1.0 FT.
PSIS1	=	0.0 DEG	PSIS2	=	180.0 DEG
US1	=	.5 MPH	US2	=	8.8 MPH
VS1	=	4.7 MPH	VS2	=	2.2 MPH
PSISD1	=	-53.3 DEG/SEC	PSISD2	=	-23.6 DEG/SEC

RELATIVE VELOCITY DATA

	VEHICLE # 1	VEHICLE # 2
SPEED CHANGE (TRAJ. + DAMAGE)	36.9 MPH	28.6 MPH
	-7.3 DEG	-4.4 DEG
SPEED CHANGE (DAMAGE ONLY)	36.6 MPH	28.6 MPH
	.0 DEG	.0 DEG
IMPACT SPEED	37.1 MPH	37.3 MPH
ENERGY DISSIPATED BY DAMAGE	93522.8 FT-LB	191574.4 FT-LB
SPEED ALONG LINE THRU CGS	36.9 MPH	37.1 MPH
SPEED ORTHOG. TO CG LINE	4.4 MPH	4.4 MPH
CLOSING VELOCITY	73.9 MPH	

SUMMARY OF DAMAGE DATA

(* INDICATES DEFAULT VALUE)

	VEHICLE # 1		VEHICLE # 2	
TYPE----------	INTERMEDIATE		INTERMEDIATE	
WEIGHT--------	3080.0 LBS.		3950.0 LBS.	
VDI-----------	12FYEW4		12FYEW5	
L-------------	34.0 IN.		35.0 IN.	
C1------------	46.5 IN.		57.0 IN.	
C2------------	35.8 IN.		49.8 IN.	
C3------------	25.2 IN.		42.7 IN.	
C4------------	14.5 IN.		35.5 IN.	
C5------------	0.0 IN.		0.0 IN.	
C6------------	0.0 IN.		0.0 IN.	
D-------------	-25.5 IN.		-23.4 IN.	
RHO-----------	1.00	*	1.00	*
ANG-----------	360.0 DEG.	*	360.0 DEG.	*

DIMENSIONS AND INERTIAL PROPERTIES

A1	=	54.7 INCHES	A2	=	54.7 INCHES
B1	=	59.2 INCHES	B2	=	59.2 INCHES
TR1	=	61.8 INCHES	TR2	=	61.8 INCHES
I1	=	29819.6 LB-SEC**2-IN	I2	=	38242.6 LB-SEC**2-IN
M1	=	7.971 LB-SEC**2/IN	M2	=	10.223 LB-SEC**2/IN
XF1	=	98.8 INCHES	XF2	=	98.8 INCHES
XR1	=	-114.0 INCHES	XR2	=	-114.0 INCHES
YS1	=	38.5 INCHES	YS2	=	38.5 INCHES

ROLLING RESISTANCE

VEHICLE # 1 VEHICLE # 2

RF----------	0.00	RF----------	0.00
LF----------	1.00	LF----------	1.00
RR----------	0.00	RR----------	0.00
LR----------	0.00	LR----------	0.00

MU---------- .50

ENTER TYPE OF CRASH RUN?
(COMPLETE,ABBREVIATED,RERUN,PRINT,BATCH,SMAC,OR END)
?RERUN

WILL THE INPUT FOR THIS RUN BE IN METRIC FORM?
(ANSWER YES OR NO)
?NO

QUESTION NUMBERS?
?1

1. TITLE?
?MRA #1 ONCE AGAIN, TO SEE IF D CHANGES

THANK YOU VERY MUCH

SUMMARY OF CRASH RESULTS

MRA #1 ONCE AGAIN, TO SEE IF D CHANGES

	VEHICLE # 1	VEHICLE # 2
SPEED CHANGE (TRAJ. + DAMAGE)	36.9 MPH	28.6 MPH
	-7.3 DEG	-4.4 DEG
SPEED CHANGE (DAMAGE ONLY)	36.6 MPH	28.6 MPH
	.0 DEG	.0 DEG
IMPACT SPEED	37.1 MPH	37.3 MPH
ENERGY DISSIPATED BY DAMAGE	93522.8 FT-LB	191574.4 FT-LB
SPEED ALONG LINE THRU CGS	36.9 MPH	37.1 MPH
SPEED ORTHOG. TO CG LINE	4.4 MPH	4.4 MPH
CLOSING VELOCITY	73.9 MPH	

ENTER TYPE OF CRASH RUN?
(COMPLETE,ABBREVIATED,RERUN,PRINT,BATCH,SMAC,OR END)
?P

SUMMARY OF CRASH RESULTS

MRA #1 ONCE AGAIN, TO SEE IF D CHANGES

VEHICLE # 1

```
**************************************************************
*           *                            *                   *
*           *      SPEED  CHANGE         *                   *
*IMPACT SPEED*         MPH               *                   *
*           *                            *      BASIS        *
*    MPH    ******************************       OF          *
```

Impact Speed MPH	Speed Change MPH: Total	Long.	Lateral	Basis of Results
				SPINOUT TRAJECTORIES AND CONSERVATION OF LINEAR MOMENTUM
37.1	36.9	-36.6	4.7	SPINOUT TRAJECTORIES AND DAMAGE
	36.6	-36.6	.0	DAMAGE DATA ONLY

VEHICLE # 2

IMPACT SPEED MPH	SPEED CHANGE MPH: TOTAL	LONG.	LATERAL	BASIS OF RESULTS
				SPINOUT TRAJECTORIES AND CONSERVATION OF LINEAR MOMENTUM
37.3	28.6	-28.6	2.2	SPINOUT TRAJECTORIES AND DAMAGE
	28.6	-28.6	.0	DAMAGE DATA ONLY

SCENE INFORMATION

	VEHICLE # 1		VEHICLE # 2	
IMPACT X-POSITION	-8.40	FT.	8.40	FT.
IMPACT Y-POSITION	1.00	FT.	-1.00	FT.
IMPACT HEADING ANGLE	0.00	DEG.	179.98	DEG.
REST X-POSITION	-7.30	FT.	.70	FT.
REST Y-POSITION	4.20	FT.	-2.50	FT.
REST HEADING ANGLE	-25.00	DEG.	162.46	DEG.
DIRECTION OF ROTATION	CCW		CCW	
AMOUNT OF ROTATION	<360		<360	

COLLISION CONDITIONS

VEHICLE # 1			VEHICLE # 2		
XC10'	=	-8.4 FT.	XC20'	=	8.4 FT.
YC10'	=	1.0 FT.	YC20'	=	-1.0 FT.
PSI10	=	0.0 DEGREES	PSI20	=	180.0 DEGREES
PSI1D0	=	0.0 DEG/SEC	PSI2D0	=	0.0 DEG/SEC
U10	=	37.1 MPH	U20	=	37.3 MPH
V10	=	0.0 MPH	V20	=	0.0 MPH

SEPARATION CONDITIONS

XCS1	=	-8.4 FT.	XCS2	=	8.4 FT.
YCS1	=	1.0 FT.	YCS2	=	-1.0 FT.
PSIS1	=	0.0 DEG	PSIS2	=	180.0 DEG
US1	=	.5 MPH	US2	=	8.8 MPH
VS1	=	4.7 MPH	VS2	=	2.2 MPH
PSISD1	=	-53.3 DEG/SEC	PSISD2	=	-23.6 DEG/SEC

RELATIVE VELOCITY DATA

	VEHICLE # 1	VEHICLE # 2
SPEED CHANGE (TRAJ. + DAMAGE)	36.9 MPH	28.6 MPH
	-7.3 DEG	-4.4 DEG
SPEED CHANGE (DAMAGE ONLY)	36.6 MPH	28.6 MPH
	.0 DEG	.0 DEG
IMPACT SPEED	37.1 MPH	37.3 MPH
ENERGY DISSIPATED BY DAMAGE	93522.8 FT-LB	191574.4 FT-LB
SPEED ALONG LINE THRU CGS	36.9 MPH	37.1 MPH
SPEED ORTHOG. TO CG LINE	4.4 MPH	4.4 MPH
CLOSING VELOCITY	73.9 MPH	

SUMMARY OF DAMAGE DATA

(* INDICATES DEFAULT VALUE)

VEHICLE # 1			VEHICLE # 2		
TYPE----------	INTERMEDIATE		TYPE----------	INTERMEDIATE	
WEIGHT-------	3080.0 LBS.		WEIGHT-------	3950.0 LBS.	
VDI-----------	12FYEW4		VDI-----------	12FYEW5	
L-------------	34.0 IN.		L-------------	35.0 IN.	
C1------------	46.5 IN.		C1------------	57.0 IN.	
C2------------	35.8 IN.		C2------------	49.8 IN.	
C3------------	25.2 IN.		C3------------	42.7 IN.	
C4------------	14.5 IN.		C4------------	35.5 IN.	
C5------------	0.0 IN.		C5------------	0.0 IN.	
C6------------	0.0 IN.		C6------------	0.0 IN.	
D-------------	-25.5 IN.		D-------------	-23.4 IN.	
RHO-----------	1.00	*	RHO-----------	1.00	*
ANG-----------	360.0 DEG.	*	ANG-----------	360.0 DEG.	*

DIMENSIONS AND INERTIAL PROPERTIES

A1	=	54.7 INCHES	A2	=	54.7 INCHES
B1	=	59.2 INCHES	B2	=	59.2 INCHES
TR1	=	61.8 INCHES	TR2	=	61.8 INCHES
I1	=	29819.6 LB-SEC**2-IN	I2	=	38242.6 LB-SEC**2-IN
M1	=	7.971 LB-SEC**2/IN	M2	=	10.223 LB-SEC**2/IN
XF1	=	98.8 INCHES	XF2	=	98.8 INCHES
XR1	=	-114.0 INCHES	XR2	=	-114.0 INCHES

```
YS1      =    38.5 INCHES                    YS2      =    38.5 INCHES

                      ROLLING RESISTANCE

   VEHICLE # 1                                       VEHICLE # 2

RF-----------      0.00                       RF-----------      0.00
LF-----------      1.00                       LF-----------      1.00
RR-----------      0.00                       RR-----------      0.00
LR-----------      0.00                       LR-----------      0.00


MU-----------       .50

ENTER TYPE OF CRASH RUN?
(COMPLETE,ABBREVIATED,RERUN,PRINT,BATCH,SMAC,OR END)
?END

                      CRASH PROGRAM COMPLETED.
   STOP

MRU=      8.564

#
```

EXAMPLE 5. MRA TEST #1 ON CRASH2A

TEST VERS
?MRA #1 TO CHECK FOR SPINOUT ERROR

2. CLASS/WEIGHTS?
?4 3080 4 3950

3. VDI/PDOF # 1?
?12FYEW4

4. VDI/PDOF # 2?
?12FYEW5

5. REST & IMPACT? (Y OR N)
?Y

6. REST COORDINATES?
?-7.3 4.2 -25. .7 -2.5 162.48

7. IMPACT COORDINATES?
?-8.4 1. 0. 8.4 -1. 180.

8. ANY SLIP ANGLES? (Y/N)
?N

10. ANY YAW VELOCITIES? (Y/N)
?N

12. SKIDDING OF # 1? (Y OR N)
?Y

13. SKIDDING STOP BEFORE REST? (Y OR N)
?N

15. CURVED PATH? (Y OR N)
?N

17. ROTATION DIRECTION #1?
?CCW

18. MORE THAN 360 DEG? (Y OR N)
?N

19. SKIDDING OF # 2? (Y OR N)
?Y

20. SKIDDING STOP BEFORE REST? (Y OR N)
?N

22. CURVED PATH? (Y OR N)
?N

```
 24. ROTATION DIRECTION # 2?
?CCW


 25. MORE THAN 360 DEG? (Y OR N)
?N


 26. TIRE-GROUND FRICTION?
?.5


 27. ROLLING RESISTANCE OPTION?(1 OR 2)
?1


 28. ROLL. RESISTANCES, INDIV. WHEELS # 1
?0 1 0 0


 29. ROLL. RESISTANCES, INDIV. WHEELS # 2
?0 1 0 0


 32. TRAJECTORY SIMULATION? (Y OR N)
?N


 38. DAMAGE DIMENSIONS? (Y OR N)
?Y


 42. END DAMAGE WIDTH #1
?34


 43. END DAMAGE DEPTH #1
?46.5 35.8 25.2 14.5


 44. END DAMAGE MIDPOINT OFFSET #1
?-22.5


 48. END DAMAGE WIDTH #2
?57 49.8 42.7 35.5

  **** SYNTAX ERROR ****
  CHECK # OF ENTRIES,  ILLEGAL CHARACTERS, ETC.



 48. END DAMAGE WIDTH #2
?-22.

  **** ENTERED DATA IS OUTLANDISH ****
  CHECK MAGNITUDE OF ENTRY WITH LIMITS SPECIFIED IN MANUAL
```



```
 48. END DAMAGE WIDTH #2
?35
```

49. END DAMAGE DEPTH #2
?57 49.8 42.7 35.5

50. END DAMAGE MIDPOINT OFFSET # 1
?-22

CRASH INPUT COMPLETED
THANK YOU VERY MUCH

S U M M A R Y   O F   C R A S H 3   R E S U L T S

MRA #1 TO CHECK FOR SPINOUT ERROR

IMPACT SPEED (TRAJECTORY AND DAMAGE)

	FORWARD	LATERAL
VEH#1	0.0 MPH	0.0 MPH
VEH#2	0.0 MPH	0.0 MPH

SPEED CHANGE (DAMAGE)

	TOTAL	LONG.	LAT.	ANG.
VEH#1	37.6 MPH	-37.5 MPH	2.3 MPH	-3.4 DEG.
VEH#2	29.3 MPH	-29.3 MPH	1.7 MPH	-3.4 DEG.

SPEED CHANGE (LINEAR MOMENTUM)

	TOTAL	LONG.	LAT.	ANG.
VEH#1	4.8 MPH	1.5 MPH	4.5 MPH	-109.0 DEG.
VEH#2	9.0 MPH	8.9 MPH	1.7 MPH	-168.9 DEG.

ENERGY DISSIPATED BY DAMAGE   VEH#1 93860.1 FT-LB   VEH#2 192251.9 FT-LB
SPEED ALONG LINE THRU CGS (LINEAR MOMENTUM)
VEH#1   0.0 MPH
VEH#2   0.0 MPH
SPEED ORTHOG. TO CG LINE (LINEAR MOMENTUM)
VEH#1   0.0 MPH
VEH#2   0.0 MPH
CLOSING VELOCITY (LINEAR MOMENTUM)
0.0 MPH

ENTER TYPE OF CRASH RUN?
(COMPLETE,ABBREVIATED,RERUN,PRINT,DOCUMENT,BATCH,SMAC,OR END)
?P

S U M M A R Y   O F   C R A S H 3   R E S U L T S

MRA #1 TO CHECK FOR SPINOUT ERROR

VEHICLE # 1

IMPACT SPEED MPH		SPEED CHANGE MPH			BASIS OF RESULTS
FWD	LAT	TOTAL	LONG.	LATERAL	
					SPINOUT TRAJECTORIES AND CONSERVATION OF LINEAR MOMENTUM
39.1	2.2	37.6	-37.5	2.3	SPINOUT TRAJECTORIES AND DAMAGE
		37.6	-37.5	2.3	DAMAGE DATA ONLY

VEHICLE # 2

IMPACT SPEED MPH		SPEED CHANGE MPH			BASIS OF RESULTS
FWD	LAT	TOTAL	LONG.	LATERAL	
					SPINOUT TRAJECTORIES AND CONSERVATION OF LINEAR MOMENTUM

```
*        *        *        *        *           *                              *
*  38.1  *   -.0  *  29.3  * -29.3  *     1.7   * SPINOUT TRAJECTORIES AND     *
*        *        *        *        *           * DAMAGE                       *
*        *        *        *        *           *                              *
********************************************************************************
                  *        *        *           *                              *
                  *  29.3  * -29.3  *     1.7   * DAMAGE DATA ONLY             *
                  *        *        *           *                              *
                  **************************************************************
```

SCENE INFORMATION

	VEHICLE # 1	VEHICLE # 2
IMPACT X-POSITION	-8.40 FT.	8.40 FT.
IMPACT Y-POSITION	1.00 FT.	-1.00 FT.
IMPACT HEADING ANGLE	0.00 DEG.	179.98 DEG.
REST X-POSITION	-7.30 FT.	.70 FT.
REST Y-POSITION	4.20 FT.	-2.50 FT.
REST HEADING ANGLE	-25.00 DEG.	162.46 DEG.
DIRECTION OF ROTATION	CCW	CCW
AMOUNT OF ROTATION	<360	<360

COLLISION CONDITIONS

VEHICLE # 1			VEHICLE # 2		
XC10′	=	-8.4 FT.	XC20′	=	8.4 FT.
YC10′	=	1.0 FT.	YC20′	=	-1.0 FT.
PSI10	=	0.0 DEGREES	PSI20	=	180.0 DEGREES
PSI1D0	=	0.0 DEG/SEC	PSI2D0	=	0.0 DEG/SEC

SEPARATION CONDITIONS

XCS1′	=	-8.4 FT.	XCS2′	=	8.4 FT.
YCS1′	=	1.0 FT.	YCS2′	=	-1.0 FT.
PSIS1	=	0.0 DEG	PSIS2	=	180.0 DEG
US1	=	1.5 MPH	US2	=	8.9 MPH
VS1	=	4.5 MPH	VS2	=	1.7 MPH
PSISD1	=	-53.3 DEG/SEC	PSISD2	=	-23.6 DEG/SEC

SUMMARY OF RESULTS

IMPACT SPEED (TRAJECTORY AND DAMAGE)

	FORWARD	LATERAL
VEH#1	0.0 MPH	0.0 MPH
VEH#2	0.0 MPH	0.0 MPH

SPEED CHANGE (DAMAGE)

	TOTAL	LONG.	LAT.	ANG.
VEH#1	37.6 MPH	-37.5 MPH	2.3 MPH	-3.4 DEG.
VEH#2	29.3 MPH	-29.3 MPH	1.7 MPH	-3.4 DEG.

SPEED CHANGE (LINEAR MOMENTUM)

	TOTAL	LONG.	LAT.	ANG.
VEH#1	4.8 MPH	1.5 MPH	4.5 MPH	-109.0 DEG.
VEH#2	9.0 MPH	8.9 MPH	1.7 MPH	-168.9 DEG.

ENERGY DISSIPATED BY DAMAGE VEH#1 93860.1 FT-LB VEH#2 192251.9 FT-LB

RELATIVE VELOCITY DATA

SPEED ALONG LINE THRU CGS (LINEAR MOMENTUM)
VEH#1 0.0 MPH
VEH#2 0.0 MPH
SPEED ORTHOG. TO CG LINE (LINEAR MOMENTUM)
VEH#1 0.0 MPH
VEH#2 0.0 MPH
CLOSING VELOCITY (LINEAR MOMENTUM)
0.0 MPH

SUMMARY OF DAMAGE DATA (* INDICATES DEFAULT VALUE)

VEHICLE # 1

TYPE----------	CATEGORY 4	
WEIGHT--------	3080.0 LBS.	
VDI-----------	12FYEW4	
L-------------	34.0 IN.	
C1------------	46.5 IN.	
C2------------	35.8 IN.	
C3------------	25.2 IN.	
C4------------	14.5 IN.	
C5------------	0.0 IN.	
C6------------	0.0 IN.	
D-------------	-22.5	
RHO-----------	1.00	*
ANG-----------	-3.4 DEG.	*
D'------------	-25.5 IN.	

VEHICLE # 2

TYPE----------	CATEGORY 4	
WEIGHT--------	3950.0 LBS.	
VDI-----------	12FYEW5	
L-------------	35.0 IN.	
C1------------	57.0 IN.	
C2------------	49.8 IN.	
C3------------	42.7 IN.	
C4------------	35.5 IN.	
C5------------	0.0 IN.	
C6------------	0.0 IN.	
D-------------	-22.0	
RHO-----------	1.00	*
ANG-----------	-3.4 DEG.	*
D'------------	-23.4 IN.	

DIMENSIONS AND INERTIAL PROPERTIES

A1	= 54.7 INCHES	A2	= 54.7 INCHES
B1	= 59.2 INCHES	B2	= 59.2 INCHES
TR1	= 61.8 INCHES	TR2	= 61.8 INCHES
I1	= 29819.6 LB-SEC**2-IN	I2	= 38242.6 LB-SEC**2-IN
M1	= 7.971 LB-SEC**2/IN	M2	= 10.223 LB-SEC**2/IN
XF1	= 98.8 INCHES	XF2	= 98.8 INCHES
XR1	= -114.0 INCHES	XR2	= -114.0 INCHES
YS1	= 38.5 INCHES	YS2	= 38.5 INCHES

ROLLING RESISTANCE

VEHICLE # 1

RF------------	0.00
LF------------	1.00
RR------------	0.00

VEHICLE # 2

RF------------	0.00
LF------------	1.00
RR------------	0.00

```
LR---------------        0.00                        LR---------------        0.00

MU---------------         .50


ENTER TYPE OF CRASH RUN?
(COMPLETE,ABBREVIATED,RERUN,PRINT,DOCUMENT,BATCH,SMAC,OR END)
?END


                    CRASH PROGRAM COMPLETED.
   STOP

MRU=      4.683

#
```

EXAMPLE 6. DEMONSTRATION OF CORRECTED TRAJECTORY SIMULATION ON CRASH2A

```
RUN Y3LDM

Y3LDM     14:41     JUN 09,'80

ILLEGAL LANGUAGE

MRU=      0.021

#ATT Y3LDM
#LAN:EXE
#RUN Y3LDM


Y3LDM     14:41     JUN 09,'80



 ENTER TYPE OF CRASH RUN?
(COMPLETE,ABBREVIATED,RERUN,PRINT,DOCUMENT,BATCH,SMAC,OR END)
?A


  TEST VERS
?CHECK TRAJECTORY SIMULATION ON CRASH2A -- RICSAC #6


  2. CLASS/WEIGHTS?
?4 4300 2 2623


  3. VDI/PDOF # 1?
?11FZEW1 -30.


  4. VDI/PDOF # 2?
?02RDEW3 30.


  5. REST & IMPACT? (Y OR N)
?Y


  6. REST COORDINATES?
?60. 11. 15. 20. 21. 242.


  7. IMPACT COORDINATES?
?0 0 0 11.1 2.67 120.


  8. ANY SLIP ANGLES? (Y/N)
?N


 10. ANY YAW VELOCITIES?  (Y/N)
?N


 12. SKIDDING OF # 1? (Y OR N)
?N
```

```
 15. CURVED PATH? (Y OR N)
?N

 17. ROTATION DIRECTION #1?
?CW

 18. MORE THAN 360 DEG? (Y OR N)
?N

 19. SKIDDING OF # 2? (Y OR N)
?Y

 20. SKIDDING STOP BEFORE REST? (Y OR N)
?N

 22. CURVED PATH? (Y OR N)
?N

 24. ROTATION DIRECTION # 2?
?CW

 25.`MORE THAN 360 DEG? (Y OR N)
?N

 26. TIRE-GROUND FRICTION?
?.87

 27. ROLLING RESISTANCE OPTION?(1 OR 2)
?1

 28. ROLL. RESISTANCES, INDIV. WHEELS # 1
?.01 .01 .2 .2

 29. ROLL. RESISTANCES, INDIV. WHEELS # 2
?.01 .01 1. .2

 32. TRAJECTORY SIMULATION? (Y OR N)
?Y

 33. STEER ANGLES #1 ?
?0 0 0 0

 34. STEER ANGLES #2 ?
?0 0 0 0

 35. TERRAIN BOUNDARY? (Y OR N)
?N
```

```
 38. DAMAGE DIMENSIONS? (Y OR N)
?Y


 42. END DAMAGE WIDTH #1
?54.5


 43. END DAMAGE DEPTH #1
?.5 .5 1.25 1.5 1.75 2.25


 44. END DAMAGE MIDPOINT OFFSET #1
?9.75


 45. SIDE DAMAGE WIDTH #2
?77


 46. SIDE DAMAGE DEPTH #2
?4. 12. 17.8 19.3 17. 8.25


 47. SIDE DAMAGE MIDPOINT OFFSET #2
?-3.25


                    CRASH INPUT COMPLETED
                    THANK YOU VERY MUCH


 E(1),E(2),E(3),E(4),E(5) =         .3075        .0432       1.0073        -.00



 +++++ RESULTS OF TRAJECTORY SIMULATION +++++


 VEHICLE # 1                          TRAJECTORY ITERATION #  1
 US =  189.9   VS =   90.2  PSISD =  0.00  SSDOT =  210.3  GAMS =   .44
 REST:   529.4    12.1  -.00     END-OF-ROT:      4.7      2.2  -.00
 POINT-ON-CURVE:      0.0     0.0
 ERRORS:        .31     .04    1.01    -.00    0.00      Q =  1.34      T =  5.45


 US1,VS1,PSISD1,SSDOT1,GAMS1,QMIN1 =    189.947    90.195     0.000   210.274


 ADJ1,ADJ2,ADJ3 =            .8171        1.2778        -.0365
 SSDOTP,PSISDP,GAMSP =         171.819        0.000           .407
 USP,VSP =        157.792       67.995


 E(1),E(2),E(3),E(4),E(5) =         .5136        .0352       1.0040        -.00



 +++++ RESULTS OF TRAJECTORY SIMULATION +++++
```

```
VEHICLE # 1                      TRAJECTORY ITERATION #  2
US =  157.8  VS =   68.0  PSISD =  0.00  SSDOT =  171.8  GAMS =   .41
REST:   365.3      7.2  -.00      END-OF-ROT:      3.9      1.6  -.00
POINT-ON-CURVE:      0.0      0.0
ERRORS:        .51    .04   1.00   -.00   0.00      Q =  1.54      T =  4.50


ADJ1,ADJ2,ADJ3 =             .9769        1.2771        -.0206
SSDOTP,PSISDP,GAMSP =         167.848        0.000          .386
USP,VSP =        155.484        63.228


E(1),E(2),E(3),E(4),E(5) =          .5278          .0344          1.0035          -.00



+++++ RESULTS OF TRAJECTORY SIMULATION +++++


VEHICLE # 1                      TRAJECTORY ITERATION #  3
US =  155.5  VS =   63.2  PSISD =  0.00  SSDOT =  167.8  GAMS =   .39
REST:   354.7      6.2  -.00      END-OF-ROT:      3.9      1.5  -.00
POINT-ON-CURVE:      0.0      0.0
ERRORS:        .53    .03   1.00   -.00   0.00      Q =  1.55      T =  4.43


ADJ1,ADJ2,ADJ3 =             .9910        1.2770        -.0122
SSDOTP,PSISDP,GAMSP =         166.329        0.000          .374
USP,VSP =        154.828        60.776


E(1),E(2),E(3),E(4),E(5) =          .5318          .0341          1.0032          -.00



+++++ RESULTS OF TRAJECTORY SIMULATION +++++


VEHICLE # 1                      TRAJECTORY ITERATION #  4
US =  154.8  VS =   60.8  PSISD =  0.00  SSDOT =  166.3  GAMS =   .37
REST:   351.7      5.8  -.00      END-OF-ROT:      3.9      1.4  -.00
POINT ON-CURVE:      0.0      0.0
ERRORS:        .53    .03   1.00   -.00   0.00      Q =  1.55      T =  4.40


ADJ1,ADJ2,ADJ3 =             .9950        1.2769        -.0073
SSDOTP,PSISDP,GAMSP =         165.506        0.000          .367
USP,VSP =        154.500        59.346


E(1),E(2),E(3),E(4),E(5) =          .5338          .0340          1.0030          -.0



+++++ RESULTS OF TRAJECTORY SIMULATION +++++
```



```
VEHICLE # 1                      TRAJECTORY ITERATION #  5
US =  154.5  VS =   59.3  PSISD =  0.00  SSDOT =  165.5  GAMS =   .37
REST:   350.3      5.6  -.00      END-OF-ROT:      3.9      1.4  -.00
```

```
POINT-ON-CURVE:      0.0       0.0
ERRORS:         .53     .03    1.00    -.00    0.00      Q =  1.55      T =  4.40


E(1),E(2),E(3),E(4),E(5) =            .2695        0.0000          .1820        0.00



+++++ RESULTS OF TRAJECTORY SIMULATION +++++


VEHICLE # 2                         TRAJECTORY ITERATION #  1
US =  114.6  VS = -276.6  PSISD =  2.40  SSDOT =  299.4  GAMS =    .92
REST:   284.8   203.6  3.84      END-OF-ROT:   247.8   172.4  3.85
POINT-ON-CURVE:   133.2     32.0
ERRORS:       .27   0.00     .18   0.00    0.00      Q =    .45      T =  2.03


US2,VS2,PSISD2,SSDOT2,GAMS2,QMIN2 =     114.648  -276.583      2.401   299.404


ADJ1,ADJ2,ADJ3 =            1.0223        1.0581         .1809
SSDOTP,PSISDP,GAMSP =          306.080         2.541        1.097
USP,VSP =         166.173     -257.044


E(1),E(2),E(3),E(4),E(5) =            .0585        0.0000          .0733        0.00



+++++ RESULTS OF TRAJECTORY SIMULATION +++++


VEHICLE # 2                         TRAJECTORY ITERATION #  2
US =  166.2  VS = -257.0  PSISD =  2.54  SSDOT =  306.1  GAMS =  1.10
REST:   242.2   237.9  4.07      END-OF-ROT:   217.5   204.6  4.08
POINT-ON-CURVE:   133.2     32.0
ERRORS:       .06   0.00     .07   0.00    0.00      Q =    .13      T =  2.03


US2,VS2,PSISD2,SSDOT2,GAMS2,QMIN2 =     166.173  -257.044      2.541   306.080
```

S U M M A R Y   O F   C R A S H 3   R E S U L T S

```
CHECK TRAJECTORY SIMULATION ON CRASH2A -- RICSAC #6

     IMPACT SPEED (TRAJECTORY AND CONSERVATION OF LINEAR MOMENTUM)
          FORWARD         LATERAL
VEH#1    24.0 MPH        0.0 MPH
VEH#2    27.6 MPH        0.0 MPH
```



```
     SPEED CHANGE (DAMAGE)
```

	TOTAL	LONG.	LAT.	ANG.
VEH#1	21.1 MPH	-18.3 MPH	10.6 MPH	-30.0 DEG.
VEH#2	34.6 MPH	-30.0 MPH	-17.3 MPH	30.0 DEG.

SPEED CHANGE (LINEAR MOMENTUM)

	TOTAL	LONG.	LAT.	ANG.
VEH#1	14.2 MPH	-13.2 MPH	5.1 MPH	-21.1 DEG.
VEH#2	23.3 MPH	-18.1 MPH	-14.6 MPH	38.8 DEG.

ENERGY DISSIPATED BY DAMAGE VEH#1 5408.8 FT-LB VEH#2 249998.8 FT-LB
SPEED ALONG LINE THRU CGS (LINEAR MOMENTUM)
VEH#1 23.4 MPH
VEH#2 7.8 MPH
SPEED ORTHOG. TO CG LINE (LINEAR MOMENTUM)
VEH#1 -5.6 MPH
VEH#2 -26.4 MPH
CLOSING VELOCITY (LINEAR MOMENTUM)
31.2 MPH

ENTER TYPE OF CRASH RUN?
(COMPLETE,ABBREVIATED,RERUN,PRINT,DOCUMENT,BATCH,SMAC,OR END)
?P

S U M M A R Y O F C R A S H 3 R E S U L T S

CHECK TRAJECTORY SIMULATION ON CRASH2A -- RICSAC #6

VEHICLE # 1

IMPACT SPEED MPH		SPEED CHANGE MPH			BASIS OF RESULTS
FWD	LAT	TOTAL	LONG.	LATERAL	
24.0	0.0	14.2	-13.2	5.1	SPINOUT TRAJECTORIES AND CONSERVATION OF LINEAR MOMENTUM

FWD	LAT	TOTAL	LONG.	LATERAL	BASIS OF RESULTS
					SPINOUT TRAJECTORIES AND DAMAGE
		21.1	-18.3	10.6	DAMAGE DATA ONLY

VEHICLE # 2

IMPACT SPEED MPH		SPEED CHANGE MPH			BASIS OF RESULTS
FWD	LAT	TOTAL	LONG.	LATERAL	
27.6	0.0	23.3	-18.1	-14.6	SPINOUT TRAJECTORIES AND CONSERVATION OF LINEAR MOMENTUM
					SPINOUT TRAJECTORIES AND DAMAGE
		34.6	-30.0	-17.3	DAMAGE DATA ONLY

SCENE INFORMATION

	VEHICLE # 1		VEHICLE # 2	
IMPACT X-POSITION	0.00	FT.	11.10	FT.
IMPACT Y-POSITION	0.00	FT.	2.67	FT.
IMPACT HEADING ANGLE	0.00	DEG.	119.99	DEG.
REST X-POSITION	60.00	FT.	20.00	FT.
REST Y-POSITION	11.00	FT.	21.00	FT.
REST HEADING ANGLE	15.00	DEG.	241.97	DEG.
END-OF-ROTATION X-POSITION	0.00	FT.		
END-OF-ROTATION Y-POSITION	0.00	FT.		
END-OF-ROTATION HEADING ANGLE	0.00	DEG.		
DIRECTION OF ROTATION	CW		CW	
AMOUNT OF ROTATION	<360		<360	

COLLISION CONDITIONS

VEHICLE # 1			VEHICLE # 2		
XC10'	=	0.0 FT.	XC20'	=	11.1 FT.
YC10'	=	0.0 FT.	YC20'	=	2.7 FT.
PSI10	=	0.0 DEGREES	PSI20	=	120.0 DEGREES
PSI1D0	=	0.0 DEG/SEC	PSI2D0	=	0.0 DEG/SEC

SEPARATION CONDITIONS

XCS1'	=	0.0 FT.	XCS2'	=	11.1 FT.
YCS1'	=	0.0 FT.	YCS2'	=	2.7 FT.
PSIS1	=	0.0 DEG	PSIS2	=	120.0 DEG
US1	=	10.8 MPH	US2	=	9.4 MPH
VS1	=	5.1 MPH	VS2	=	-14.6 MPH
PSISD1	=	0.0 DEG/SEC	PSISD2	=	145.6 DEG/SEC

SUMMARY OF RESULTS

IMPACT SPEED (TRAJECTORY AND CONSERVATION OF LINEAR MOMENTUM)

	FORWARD	LATERAL
VEH#1	24.0 MPH	0.0 MPH
VEH#2	27.6 MPH	0.0 MPH

SPEED CHANGE (DAMAGE)

	TOTAL	LONG.	LAT.	ANG.
VEH#1	21.1 MPH	-18.3 MPH	10.6 MPH	-30.0 DEG.
VEH#2	34.6 MPH	-30.0 MPH	-17.3 MPH	30.0 DEG.

SPEED CHANGE (LINEAR MOMENTUM)

	TOTAL	LONG.	LAT.	ANG.
VEH#1	14.2 MPH	-13.2 MPH	5.1 MPH	-21.1 DEG.
VEH#2	23.3 MPH	-18.1 MPH	-14.6 MPH	38.8 DEG.

ENERGY DISSIPATED BY DAMAGE VEH#1 5408.8 FT-LB VEH#2 249998.8 FT-LB

RELATIVE VELOCITY DATA

SPEED ALONG LINE THRU CGS (LINEAR MOMENTUM)
VEH#1 23.4 MPH
VEH#2 7.8 MPH
SPEED ORTHOG. TO CG LINE (LINEAR MOMENTUM)
VEH#1 -5.6 MPH
VEH#2 -26.4 MPH
CLOSING VELOCITY (LINEAR MOMENTUM)
31.2 MPH

TRAJECTORY SIMULATION RESULTS

++++ VEHICLE # 1 DID NOT CONVERGE ++++
++++ VEHICLE # 2 CONVERGED O.K. ++++

NRUNS(1)	=	5	NRUNS(2)	=	2
E1(1)	=	.308	E2(1)	=	.059
E1(2)	=	.043	E2(2)	=	0.000
E1(3)	=	1.007	E2(3)	=	.073

```
E1(4)      =   -.000                E2(4)      =   0.000
E1(5)      =   0.000                E2(5)      =   0.000
QMIN1      =   1.336                QMIN2      =    .132


SUMMARY OF DAMAGE DATA              (* INDICATES DEFAULT VALUE)

          VEHICLE # 1                          VEHICLE # 2

TYPE----------CATEGORY 4             TYPE----------CATEGORY 2
WEIGHT--------   4300.0 LBS.         WEIGHT--------   2623.0 LBS.
VDI-----------11FZEW1                VDI-----------02RDEW3
L-------------     54.5 IN.          L-------------     77.0 IN.
C1------------       .5 IN.          C1------------      4.0 IN.
C2------------       .5 IN.          C2------------     12.0 IN.
C3------------      1.3 IN.          C3------------     17.8 IN.
C4------------      1.5 IN.          C4------------     19.3 IN.
C5------------      1.8 IN.          C5------------     17.0 IN.
C6------------      2.3 IN.          C6------------      8.3 IN.
D-------------      9.8              D-------------     -3.3
RHO-----------     1.00        *     RHO-----------     1.00        *
ANG-----------    -30.0 DEG.         ANG-----------     30.0 DEG.
D'------------     16.4 IN.          D'------------      -.5 IN.

               DIMENSIONS AND INERTIAL PROPERTIES

A1       =     54.7 INCHES           A2       =     46.3 INCHES
B1       =     59.2 INCHES           B2       =     50.1 INCHES
TR1      =     61.8 INCHES           TR2      =     54.6 INCHES
I1       =  41631.2 LB-SEC**2-IN     I2       =  20032.3 LB-SEC**2-IN
M1       =   11.128 LB-SEC**2/IN     M2       =    6.788 LB-SEC**2/IN
XF1      =     98.8 INCHES           XF2      =     83.3 INCHES
XR1      =   -114.0 INCHES           XR2      =    -91.6 INCHES
YS1      =     38.5 INCHES           YS2      =     33.6 INCHES

               ROLLING RESISTANCE

    VEHICLE # 1                              VEHICLE # 2

RF------------      .01              RF------------      .01
LF------------      .01              LF------------      .01
RR------------      .20              RR------------     1.00
LR------------      .20              LR------------      .20


MU------------      .87


ENTER TYPE OF CRASH RUN?
(COMPLETE,ABBREVIATED,RERUN,PRINT,DOCUMENT,BATCH,SMAC,OR END)
?END
```

```
                    CRASH PROGRAM COMPLETED.
          STOP

     MRU=      22.269

     #
```

EXAMPLE 7. DEMONSTRATION OF CORRECTED TRAJECTORY SIMULATION ON CRASH2

```
RNH CRA2LDM


ENTER TYPE OF CRASH RUN?
(COMPLETE,ABBREVIATED,RERUN,PRINT,BATCH,SMAC,OR END)
?A


WILL THE INPUT FOR THIS RUN BE IN METRIC FORM?
(ANSWER YES OR NO)
?NO

  1. TITLE?
?RICSAC #6 TO TEST TRAJECTORY SIMULATION PATCH

  2. SIZE CATEGORIES?
?I S

  3. VDI, #1
?11FZEW1

  4. VDI, #2
?02RDEW3

  5. ACTUAL WEIGHTS? (Y OR N)
?Y

  6. WEIGHT #1
?4300

  7. WEIGHT #2
?2623

  8. REST & IMPACT? (Y OR N)
?Y

  9. REST COORDINATES?
?60. 11. 15. 20. 21. 242.

 10. IMPACT COORDINATES?
?0 0 0 11.1 2.67 120.

 11. SKIDDING OF # 1? (Y OR N)
?N
```

```
 14. CURVED PATH? (Y OR N)
?N

 16. ROTATION DIRECTION #1?
?CW

 17. MORE THAN 360 DEG? (Y OR N)
?N

 18. SKIDDING OF # 2? (Y OR N)
?Y

 19. SKIDDING STOP BEFORE REST? (Y OR N)
?N

 21. CURVED PATH? (Y OR N)
?N

 23. ROTATION DIRECTION # 2?
?CW

 24. MORE THAN 360 DEG? (Y OR N)
?N

 25. TIRE-GROUND FRICTION?
?.87

 26. ROLLING RESISTANCE OPTION?(1 OR 2)
?1

 27. ROLL. RESISTANCES, INDIV. WHEELS # 1
?.01 .01 .2 .2

 28. ROLL. RESISTANCES, INDIV. WHEELS # 2
?.01 .01 1. .2

 31. TRAJECTORY SIMULATION? (Y OR N)
?Y

 32. STEER ANGLES #1 ?
?0 0 0 0

 33. STEER ANGLES #2 ?
?0 0 0 0

 34. TERRAIN BOUNDARY? (Y OR N)
?N

 37. DAMAGE DIMENSIONS? (Y OR N)
?Y

 41. END DAMAGE WIDTH #1
?54.5

 42. END DAMAGE DEPTH #1
?.5 .5 1.25 1.5 1.75 2.25

 43. END DAMAGE MIDPOINT OFFSET #1
?9/_.75

 44. SIDE DAMAGE WIDTH #2
?77

 45. SIDE DAMAGE DEPTH #2
?4. 12. 17.8 19.3 17. 8.25
```

```
 46. SIDE DAMAGE MIDPOINT OFFSET #2
?-3.25

 52. FORCE DIRECTIONS (Y OR N)
?Y

 53. PRINCIPAL FORCE ANGLE #1?
?-30.

 54. PRINCIPAL FORCE ANGLE #2?
?30.

                         THANK YOU VERY MUCH

 VEHICLE # 1                          TRAJECTORY ITERATION #  1
 US =  223.6  VS =   41.0  PSISD =  0.00  SSDOT =  227.3  GAMS =    .18
 REST:   734.0      2.7  -.00     END-OF-ROT:    22.2     2.7  -.00
 POINT-ON-CURVE:      0.0     0.0
 ERRORS:        .18     .19   1.00    -.00    0.00      Q =  1.27      T =  6.40

 VEHICLE # 1                          TRAJECTORY ITERATION #  2
 US =  153.6  VS =   40.8  PSISD =  0.00  SSDOT =  158.9  GAMS =    .26
 REST:   345.8      -.0  -.00     END-OF-ROT:    15.2     2.5  -.00
 POINT-ON-CURVE:      0.0     0.0
 ERRORS:        .54     .13   1.00    -.00    0.00      Q =  1.61      T =  4.30

 VEHICLE # 1                          TRAJECTORY ITERATION #  3
 US =  151.0  VS =   51.1  PSISD =  0.00  SSDOT =  159.4  GAMS =    .33
 REST:   334.1       .9  -.00     END-OF-ROT:    14.9     3.5  -.00
 POINT-ON-CURVE:      0.0     0.0
 ERRORS:        .56     .13   1.01    -.00    0.00      Q =  1.63      T =  4.20

 VEHICLE # 1                          TRAJECTORY ITERATION #  4
 US =  151.7  VS =   58.8  PSISD =  0.00  SSDOT =  162.7  GAMS =    .37
 REST:   337.6      1.7  -.00     END-OF-ROT:    15.0     4.2  -.00
 POINT-ON-CURVE:      0.0     0.0
 ERRORS:        .55     .13   1.00    -.00    0.00      Q =  1.62      T =  4.30

 VEHICLE # 1                          TRAJECTORY ITERATION #  5
 US =  152.3  VS =   63.7  PSISD =  0.00  SSDOT =  165.1  GAMS =    .40
 REST:   340.5      3.3   .01     END-OF-ROT:    15.1     4.7  -.00
 POINT-ON-CURVE:      0.0     0.0
 ERRORS:        .55     .13    .97    -.00    0.00      Q =  1.58      T =  4.30

 VEHICLE # 2                          TRAJECTORY ITERATION #  1
 US =  126.2  VS = -271.5  PSISD =  2.40  SSDOT =  299.4  GAMS =    .96
 REST:   271.9    207.9  3.84     END-OF-ROT:   246.5   184.4  3.88
 POINT-ON-CURVE:    133.2    32.0
 ERRORS:        .22    0.00    .18    0.00    0.00      Q =   .40      T =  2.10

 VEHICLE # 2                          TRAJECTORY ITERATION #  2
 US =  168.7  VS = -258.1  PSISD =  2.54  SSDOT =  308.4  GAMS =  1.10
 REST:   243.0    241.1  4.04     END-OF-ROT:   225.3   216.4  4.09
 POINT-ON-CURVE:    133.2    32.0
 ERRORS:        .05    0.00    .08    0.00    0.00      Q =   .13      T =  2.10


                      SUMMARY OF CRASH RESULTS
```



```
 RICSAC #6 TO TEST TRAJECTORY SIMULATION PATCH
```

```
                                              VEHICLE # 1    VEHICLE # 2

SPEED CHANGE (TRAJ. ONLY)                        11.9 MPH        19.5 MPH
                                                -11.3 DEG        48.7 DEG
SPEED CHANGE (DAMAGE ONLY)                       21.1 MPH        34.6 MPH
                                                -30.0 DEG        30.0 DEG
IMPACT SPEED                                     24.4 MPH        22.5 MPH
ENERGY DISSIPATED BY DAMAGE                    5409.2 FT-LB 249929.9 FT-LB
SPEED ALONG LINE THRU CGS                        24.0 MPH         7.7 MPH
SPEED ORTHOG. TO CG LINE                         -4.2 MPH       -21.1 MPH
CLOSING VELOCITY                                 31.8 MPH


ENTER TYPE OF CRASH RUN?
(COMPLETE,ABBREVIATED,RERUN,PRINT,BATCH,SMAC,OR END)
?P


                       SUMMARY OF CRASH RESULTS

RICSAC #6 TO TEST TRAJECTORY SIMULATION PATCH


                           VEHICLE # 1
*************************************************************
*           *                            *                  *
*           *        SPEED  CHANGE       *                  *
*IMPACT SPEED*            MPH            *                  *
*           *                            *       BASIS      *
*    MPH    ******************************         OF       *
*           *         *         *        *      RESULTS     *
*           *  TOTAL  *  LONG.  * LATERAL *                  *
*           *         *         *        *                  *
*************************************************************
*           *         *         *        *                  *
*           *         *         *        *SPINOUT TRAJECTORIES*
*       24.4*     11.9*    -11.7*     2.3*AND CONSERVATION OF *
*           *         *         *        *LINEAR MOMENTUM   *
*           *         *         *        *                  *
*************************************************************
*           *         *         *        *                  *
*           *         *         *        *SPINOUT TRAJECTORIES*
*           *         *         *        *       AND        *
*           *         *         *        *      DAMAGE      *
*           *         *         *        *                  *
*************************************************************
*           *         *         *        *                  *
*           *     21.1*    -18.3*    10.6*  DAMAGE DATA ONLY *
*           *         *         *        *                  *
*************************************************************


                           VEHICLE # 2
*************************************************************
*           *                            *                  *
*           *        SPEED  CHANGE       *                  *
*IMPACT SPEED*            MPH            *                  *
*           *                            *       BASIS      *
*    MPH    ******************************         OF       *
*           *         *         *        *      RESULTS     *
*           *  TOTAL  *  LONG.  * LATERAL *                  *
*           *         *         *        *                  *
**************************************       ***************************
*           *         *         *        *                  *
```

22.5	19.5	-12.9	-14.7	SPINOUT TRAJECTORIES AND CONSERVATION OF LINEAR MOMENTUM
				SPINOUT TRAJECTORIES AND DAMAGE
	34.6	-30.0	-17.3	DAMAGE DATA ONLY

SCENE INFORMATION

	VEHICLE # 1	VEHICLE # 2
IMPACT X-POSITION	-.72 FT.	11.43 FT.
IMPACT Y-POSITION	0.00 FT.	2.10 FT.
IMPACT HEADING ANGLE	0.00 DEG.	119.99 DEG.
REST X-POSITION	60.00 FT.	20.00 FT.
REST Y-POSITION	11.00 FT.	21.00 FT.
REST HEADING ANGLE	15.00 DEG.	241.97 DEG.
END-OF-ROTATION X-POSITION	0.00 FT.	
END-OF-ROTATION Y-POSITION	0.00 FT.	
END-OF-ROTATION HEADING ANGLE	0.00 DEG.	
DIRECTION OF ROTATION	CW	CW
AMOUNT OF ROTATION	<360	<360

COLLISION CONDITIONS

VEHICLE # 1			VEHICLE # 2		
XC10'	=	-.7 FT.	XC20'	=	11.4 FT.
YC10'	=	0.0 FT.	YC20'	=	2.1 FT.
PSI10	=	0.0 DEGREES	PSI20	=	120.0 DEGREES
PSI1D0	=	0.0 DEG/SEC	PSI2D0	=	0.0 DEG/SEC
U10	=	24.4 MPH	U20	=	22.5 MPH
V10	=	0.0 MPH	V20	=	0.0 MPH

SEPARATION CONDITIONS

XCS1	=	0.0 FT.	XCS2	=	11.1 FT.
YCS1	=	0.0 FT.	YCS2	=	2.7 FT.
PSIS1	=	0.0 DEG	PSIS2	=	120.0 DEG
US1	=	12.7 MPH	US2	=	9.6 MPH
VS1	=	2.3 MPH	VS2	=	-14.7 MPH
PSISD1	=	0.0 DEG/SEC	PSISD2	=	145.4 DEG/SEC

RELATIVE VELOCITY DATA

	VEHICLE # 1	VEHICLE # 2
SPEED CHANGE (TRAJ. ONLY)	11.9 MPH	19.5 MPH
	-11.3 DEG	48.7 DEG
SPEED CHANGE (DAMAGE ONLY)	21.1 MPH	34.6 MPH

	-30.0 DEG	30.0 DEG
IMPACT SPEED	24.4 MPH	22.5 MPH
ENERGY DISSIPATED BY DAMAGE	5409.2 FT-LB	249929.9 FT-LB
SPEED ALONG LINE THRU CGS	24.0 MPH	7.7 MPH
SPEED ORTHOG. TO CG LINE	-4.2 MPH	-21.1 MPH
CLOSING VELOCITY	31.8 MPH	

TRAJECTORY SIMULATION RESULTS

++++ VEHICLE # 1 DID NOT CONVERGE ++++
++++ VEHICLE # 2 CONVERGED O.K. ++++

NRUNS(1) =	5	NRUNS(2) =	2
E1(1) =	.178	E2(1) =	.046
E1(2) =	.185	E2(2) =	0.000
E1(3) =	1.002	E2(3) =	.085
E1(4) =	-.000	E2(4) =	0.000
E1(5) =	0.000	E2(5) =	0.000
QMIN1 =	1.273	QMIN2 =	.131

SUMMARY OF DAMAGE DATA (* INDICATES DEFAULT VALUE)

VEHICLE # 1			VEHICLE # 2		
TYPE----------	INTERMEDIATE		TYPE----------	SUBCOMPACT	
WEIGHT--------	4300.0 LBS.		WEIGHT--------	2623.0 LBS.	
VDI-----------	11FZEW1		VDI-----------	02RDEW3	
L-------------	54.5 IN.		L-------------	77.0 IN.	
C1------------	.5 IN.		C1------------	4.0 IN.	
C2------------	.5 IN.		C2------------	12.0 IN.	
C3------------	1.3 IN.		C3------------	17.8 IN.	
C4------------	1.5 IN.		C4------------	19.3 IN.	
C5------------	1.8 IN.		C5------------	17.0 IN.	
C6------------	2.3 IN.		C6------------	8.3 IN.	
D-------------	16.4 IN.		D-------------	-.5 IN.	
RHO-----------	1.00	*	RHO-----------	1.00	*
ANG-----------	330.0 DEG.		ANG-----------	30.0 DEG.	

DIMENSIONS AND INERTIAL PROPERTIES

A1 =	54.7 INCHES	A2 =	46.3 INCHES
B1 =	59.2 INCHES	B2 =	50.1 INCHES
TR1 =	61.8 INCHES	TR2 =	54.6 INCHES
I1 =	41631.2 LB-SEC**2-IN	I2 =	20032.3 LB-SEC**2-IN
M1 =	11.128 LB-SEC**2/IN	M2 =	6.788 LB-SEC**2/IN
XF1 =	98.8 INCHES	XF2 =	83.3 INCHES
XR1 =	-114.0 INCHES	XR2 =	-91.6 INCHES
YS1 =	38.5 INCHES	YS2 =	33.6 INCHES

ROLLING RESISTANCE

VEHICLE # 1		VEHICLE # 2	
RF------------	.01	RF------------	.01
LF------------	.01	LF------------	.01
RR------------	.20	RR------------	1.00
LR------------	.20	LR------------	.20

MU------------ .87

```
 ENTER TYPE OF CRASH RUN?
 (COMPLETE,ABBREVIATED,RERUN,PRINT,BATCH,SMAC,OR END)
?end


                              CRASH PROGRAM COMPLETED.
    STOP

MRU=      10.293

#
```

APPENDIX D

SUMMARY REPORTS OF DAMAGE TEST CASES

RICSAC CASES

DAMAGE COEFFICIENTS (A,B,G) TEST SUMMARY

VEHICLE

MAKE: CHEVROLET

MODEL: CHEVELLE

YEAR:

COLLISION

SOURCE: RICSAC VOL. 4, TEST 1

TYPE: 60^{o} FRONT-SIDE

OTHER OBJECT: FORD PINTO

DATA & RESULTS

CDC	PDOF	L (IN)	C_1-C_6 (IN)	D (IN)	WEIGHT (LBS)	WHEELBASE CLASS	STIFF-NESS CLASS	MEASURED V IMPACT (MPH)	MEASURED Δ V (MPH)	SOURCE OF A,B,G	ESTIMATED Δ V (MPH)
11FZEW2	-30	46	4, 5.5, 7, 10.2, 12.1, 14.8	14.3	4621	4	4	19.8	12.2	CRASH3	18.5
										CRASH2A	18.5
										CRASH2 R,M	18.5
										SRL-1	19.5

DAMAGE COEFFICIENTS (A,B,G) TEST SUMMARY

VEHICLE

MAKE: FORD

MODEL: PINTO

YEAR:

COLLISION

SOURCE: RICSAC VOL.4, TEST 1

TYPE: 60° FRONT-SIDE

OTHER OBJECT: CHEVROLET CHEVELLE

DATA & RESULTS

CDC	PDOF	L (IN)	C_1-C_6 (IN)	D (IN)	WEIGHT (LBS)	WHEELBASE CLASS	STIFFNESS CLASS	MEASURED V IMPACT (MPH)	MEASURED ΔV (MPH)	SOURCE OF A,B,G	ESTIMATED ΔV (MPH)
)1RDEW3	30	113.3	.5, 12., 10.6, 11.8, 9, 4.1	21.8	3082	2	2	19.8	15.6	CRASH3	27.7
										CRASH2A	27.7
										CRASH2-R,M	27.7
										SRL-1	29.2

DAMAGE COEFFICIENTS (A,B,G) TEST SUMMARY

VEHICLE

MAKE: CHEVROLET

MODEL: CHEVELLE

YEAR:

COLLISION

SOURCE: RICSAC VOL. 4, TEST 2

TYPE: 60° FRONT-SIDE

OTHER OBJECT: FORD PINTO

DATA & RESULTS

CDC	PDOF	L (IN)	C_1-C_6 (IN)	D (IN)	WEIGHT (LBS)	WHEELBASE CLASS	STIFF-NESS CLASS	MEASURED V IMPACT (MPH)	MEASURED Δ V (MPH)	SOURCE OF A,B,G	ESTIMATED Δ V (MPH)
11FDEW2	-30	75.5	.5, 2.4, 3.7, 6.9,12 16.5	0	4621	4	4	31.5	19.6	CRASH3	31.1
										CRASH2A	31.1
										CRASH2-R	19.3
										CRASH2-M	31.1

NOTE: CRASH2-R has non-collinear PDOF angles entered.

DAMAGE COEFFICIENTS (A,B,G) TEST SUMMARY

VEHICLE

MAKE: FORD

MODEL: PINTO

YEAR:

COLLISION

SOURCE: RICSAC VOL.4, TEST 2

TYPE: 60^{o} FRONT-SIDE

OTHER OBJECT: CHEVROLET CHEVELLE

DATA & RESULTS

CDC	PDOF	L (IN)	C_1-C_6 (IN)	D (IN)	WEIGHT (LBS)	WHEELBASE CLASS	STIFF-NESS CLASS	MEASURED V IMPACT (MPH)	MEASURED Δ V (MPH)	SOURCE OF A,B,G	ESTIMATED Δ V (MPH)
02RDEW4	30	118.5	6.75, 22.75, 23.5, 21.3, 10, 0	13.7	3081	2	2	31.5	28.9	CRASH3	46.7
										CRASH2A	46.6
										CRASH2-R	29.0
										CRASH2-M	46.6

NOTE: CRASH2-R has non-collinear force angles entered.

DAMAGE COEFFICIENTS (A,B,G) TEST SUMMARY

VEHICLE

MAKE: CHEVROLET

MODEL: CHEVELLE

YEAR:

COLLISION

SOURCE: RICSAC VOL. 4, TEST 6

TYPE: 60^{o} FRONT-SIDE

OTHER OBJECT: VOLKSWAGEN RABBIT

DATA & RESULTS

CDC	PDOF	L (IN)	C_1-C_6 (IN)	D (IN)	WEIGHT (LBS)	WHEELBASE CLASS	STIFF-NESS CLASS	MEASURED V IMPACT (MPH)	MEASURED Δ V (MPH)	SOURCE OF A,B,G	ESTIMATED Δ V (MPH)
11FZEW1	- 30	54.5	.5, .5, 1.25, 1.5, 1.75, 2.25	9.75	4300	4	4	21.5	9.2	CRASH3	21.3
										CRASH2A	21.1
										CRASH2-R	12.7
										CRASH2-M	21.1

NOTE: CRASH2-R result based on non-collinear PDOF angles.

DAMAGE COEFFICIENTS (A,B,G) TEST SUMMARY

VEHICLE

MAKE: VOLKSWAGEN

MODEL: RABBIT

YEAR:

COLLISION

SOURCE: RICSAC VOL.4, TEST 6

TYPE: 60^{o} FRONT-SIDE

OTHER OBJECT: CHEVROLET CHEVELLE

DATA & RESULTS

CDC	PDOF	L (IN)	C_1-C_6 (IN)	D (IN)	WEIGHT (LBS)	WHEELBASE CLASS	STIFF-NESS CLASS	MEASURED V IMPACT (MPH)	MEASURED Δ V (MPH)	SOURCE OF A,B,G	ESTIMATED Δ V (MPH)
02RDEW3	30	77	4, 12, 17.8, 19.3 17, 8.25	-3.25	2623	2	2	21.5	11.9	CRASH3	35.0
										CRASH2A	34.6
										CRASH2-R	20.9
										CRASH2-M	34.6

NOTE: CRASH2-R result based on non-collinear PDOF angles.

DAMAGE COEFFICIENTS (A,B,G) TEST SUMMARY

VEHICLE

MAKE: CHEVROLET

MODEL: CHEVELLE

YEAR:

COLLISION

SOURCE: RICSAC VOL.4, TEST 7

TYPE: 60^{o} FRONT-SIDE

OTHER OBJECT: VOLKSWAGEN RABBIT

DATA & RESULTS

CDC	PDOF	L (IN)	C_1-C_6 (IN)	D (IN)	WEIGHT (LBS)	WHEELBASE CLASS	STIFF-NESS CLASS	MEASURED V IMPACT (MPH)	MEASURED Δ V (MPH)	SOURCE OF A,B,G	ESTIMATED Δ V (MPH)
11FDEW1	-30	66	0, 1.25, 2, 3.75, 5, 6.25	4	3700	4	4	29.1	12.0	CRASH3	27.0
										CRASH2A	26.8
										CRASH2-R	16.3
										CRASH2-M	26.8

NOTE: CRASH2-R result based on non-collinear PDOF angles.

DAMAGE COEFFICIENTS (A,B,G) TEST SUMMARY

VEHICLE

MAKE: VOLKSWAGEN

MODEL: RABBIT

YEAR:

COLLISION

SOURCE: RICSAC VOL.4, TEST 7

TYPE: 60° FRONT-SIDE

OTHER OBJECT: CHEVROLET CHEVELLE

DATA & RESULTS

CDC	PDOF	L (IN)	C_1-C_6 (IN)	D (IN)	WEIGHT (LBS)	WHEELBASE CLASS	STIFF-NESS CLASS	MEASURED V IMPACT (MPH)	MEASURED Δ V (MPH)	SOURCE OF A,B,G	ESTIMATED Δ V (MPH)
02RDEW4	30	108.5	0, 11, 17.75, 21, 21.25, 7.25	-8.5	1700	2	2	29.1	16.5	CRASH3	58.7
										CRASH2A	58.3
										CRASH2-R	35.5
										CRASH2-M	58.3

NOTE: CRASH2-R result based on non-collinear PDOF angles.

DAMAGE COEFFICIENTS (A,B,G) TEST SUMMARY

VEHICLE

MAKE: CHEVROLET

MODEL: CHEVELLE

YEAR:

COLLISION

SOURCE: RICSAC VOL.4, TEST 8

TYPE: 90° FRONT-SIDE

OTHER OBJECT: CHEVROLET CHEVELLE

DATA & RESULTS

CDC	PDOF	L (IN)	C_1-C_6 (IN)	D (IN)	WEIGHT (LBS)	WHEELBASE CLASS	STIFF-NESS CLASS	MEASURED V IMPACT (MPH)	MEASURED ΔV (MPH)	SOURCE OF A,B,G	ESTIMATED ΔV (MPH)
12FDEW1	-45	73	2.7, 3.6	0	4479	4	4	20.75	15.3	CRASH3	10.0
										CRASH2A	10.0
										CRASH2-R,M	10.0

DAMAGE COEFFICIENTS (A,B,G) TEST SUMMARY

VEHICLE

MAKE: CHEVROLET

MODEL: CHEVELLE

YEAR:

COLLISION

SOURCE: RICSAC VOL. 4, TEST 8

TYPE: 90^{o} FRONT SIDE

OTHER OBJECT: CHEVROLET CHEVELLE

DATA & RESULTS

CDC	PDOF	L (IN)	C_1-C_6 (IN)	D (IN)	WEIGHT (LBS)	WHEELBASE CLASS	STIFF-NESS CLASS	MEASURED V IMPACT (MPH)	MEASURED ΔV (MPH)	SOURCE OF A,B,G	ESTIMATED ΔV (MPH)
03RYEW2	45	84.5	6.2, 8.3, 9.2, 5.9, 4.4, .8	15	4710	4	4	20.75	10.7	CRASH3	9.5
										CRASH2A	9.5
											9.5

DAMAGE COEFFICIENTS (A,B,G) TEST SUMMARY

VEHICLE

MAKE: HONDA

MODEL: CIVIC

YEAR:

COLLISION

SOURCE: RICSAC VOL. 4, TEST 9

TYPE: 90° FRONT-SIDE

OTHER OBJECT: FORD TORINO

DATA & RESULTS

CDC	PDOF	L (IN)	C_1-C_6 (IN)	D (IN)	WEIGHT (LBS)	WHEELBASE CLASS	STIFF-NESS CLASS	MEASURED V IMPACT (MPH)	MEASURED Δ V (MPH)	SOURCE OF A,B,G	ESTIMATED Δ V (MPH)
11FDEW2	-65	49.75	5, 5.75, 12.5, 7.5 7.5, 9.5	1.63	2256	1	1	21.2	21.4	CRASH3	21.9
										CKASH2A	19.1
										CRASH2-R,M	19.1

DAMAGE COEFFICIENTS (A,B,G) TEST SUMMARY

VEHICLE

MAKE: FORD

MODEL: TORINO

YEAR:

COLLISION

SOURCE: RICSAC VOL. 4, TEST 9

TYPE: 90^{o} FRONT-SIDE

OTHER OBJECT: HONDA CIVIC

DATA & RESULTS

CDC	PDOF	L (IN)	C_1-C_6 (IN)	D (IN)	WEIGHT (LBS)	WHEELBASE CLASS	STIFF-NESS CLASS	MEASURED V IMPACT (MPH)	MEASURED Δ V (MPH)	SOURCE OF A,B,G	ESTIMATED Δ V (MPH)
02RFEW2	25	54.5	7.75, 4.6, 4.75, 3.3, 2.75, 1.5	68	4900	4	4	21.2	8.9	CRASH3	10.1
										CRASH2A	8.8
										CRASH2-R,M	8.8

DAMAGE COEFFICIENTS (A,B,G) TEST SUMMARY

VEHICLE

MAKE: HONDA

MODEL: CIVIC

YEAR:

COLLISION

SOURCE: RICSAC VOL. 4, TEST 10

TYPE: 90° FRONT-SIDE

OTHER OBJECT: FORD TORINO

DATA & RESULTS

CDC	PDOF	L (IN)	C_1-C_6 (IN)	D (IN)	WEIGHT (LBS)	WHEELBASE CLASS	STIFFNESS CLASS	MEASURED V IMPACT (MPH)	MEASURED Δ V (MPH)	SOURCE OF A,B,G	ESTIMATED Δ V (MPH)
10FDEW2	-65	47.5	7, 10.2, 14, 8.9,7, 9	-2.75	2306	1	1	33.3	35.1	CRASH3	24.7
										CRASH2A	22.4
										CRASH2-R,M	22.4

DAMAGE COEFFICIENTS (A,B,G) TEST SUMMARY

VEHICLE

MAKE: FORD

MODEL: TORINO

YEAR:

COLLISION

SOURCE: RICSAC VOL. 4, TEST 10

TYPE: 90° FRONT-SIDE

OTHER OBJECT: HONDA CIVIC

DATA & RESULTS

CDC	PDOF	L (IN)	C_1-C_6 (IN)	D (IN)	WEIGHT (LBS)	WHEELBASE CLASS	STIFF-NESS CLASS	MEASURED V IMPACT (MPH)	MEASURED Δ V (MPH)	SOURCE OF A,B,G	ESTIMATED Δ V (MPH)
01RFEW2	25	53	9.2, 6.5, 6.1, 5.3, 4.5, .5	66.5	4720	4	4	33.3	14.1	CRASH3	12.0
										CRASH2A	10.9
										CRASH2-R,M	10.9

DAMAGE COEFFICIENTS (A,B,G) TEST SUMMARY

VEHICLE

MAKE: CHEVROLET

MODEL: VEGA

YEAR:

COLLISION

SOURCE: RICSAC VOL. 4, TEST 11

TYPE: 10^{o} FRONT-FRONT

OTHER OBJECT: FORD TORINO

DATA & RESULTS

CDC	PDOF	L (IN)	C_1-C_6 (IN)	D (IN)	WEIGHT (LBS)	WHEELBASE CLASS	STIFF-NESS CLASS	MEASURED V IMPACT (MPH)	MEASURED Δ V (MPH)	SOURCE OF A,B,G	ESTIMATED Δ V (MPH)
12FYEW3	5	32.5	22, 20.2, 18.5, 16.8, 15, 12.5	-12.75	3041	2	2	20.4	24.0	CRASH3	20.8
										CRASH2-R,M	21.1
										CRASH2A	22.1

DAMAGE COEFFICIENTS (A,B,G) TEST SUMMARY

VEHICLE

MAKE: FORD

MODEL: TORINO

YEAR:

COLLISION

SOURCE: RICSAC VOL.4, TEST 11

TYPE: 10° FRONT-FRONT

OTHER OBJECT: CHEVROLET VEGA

DATA & RESULTS

CDC	PDOF	L (IN)	C_1-C_6 (IN)	D (IN)	WEIGHT (LBS)	WHEELBASE CLASS	STIFFNESS CLASS	MEASURED V IMPACT (MPH)	MEASURED Δ V (MPH)	SOURCE OF A,B,G	ESTIMATED Δ V (MPH)
12FYEW3	-5	32.26	29.5, 26.25, 23, 18.7, 14.3, 11	-12.9	4850	4	4	20.4	15.7	CRASH3	13.0
										CRASH2-R,M	13.2
										CRASH2A	13.9

DAMAGE COEFFICIENTS (A,B,G) TEST SUMMARY

VEHICLE

MAKE: CHEVROLET

MODEL: VEGA

YEAR:

COLLISION

SOURCE: RICSAC VOL.4, TEST 12

TYPE: 10° FRONT-FRONT

OTHER OBJECT: FORD TORINO

DATA & RESULTS

CDC	PDOF	L (IN)	C_1-C_6 (IN)	D (IN)	WEIGHT (LBS)	WHEELBASE CLASS	STIFF-NESS CLASS	MEASURED V IMPACT (MPH)	MEASURED ΔV (MPH)	SOURCE OF A,B,G	ESTIMATED ΔV (MPH)
12FYEW4	5	32	38.6, 34.6, 29.5, 26, 19.6, 14.25	2.75	3130	2	2	31.5	40.1	CRASH3	26.2
										CRASH2-R,M	28.2
										CRASH2A	28.4

DAMAGE COEFFICIENTS (A,B,G) TEST SUMMARY

VEHICLE

MAKE: FORD

MODEL: TORINO

YEAR:

COLLISION

SOURCE: RICSAC VOL.4, TEST 12

TYPE: 10^o FRONT-FRONT

OTHER OBJECT: CHEVROLET VEGA

DATA & RESULTS

CDC	PDOF	L (IN)	C_1-C_6 (IN)	D (IN)	WEIGHT (LBS)	WHEELBASE CLASS	STIFF-NESS CLASS	MEASURED V IMPACT (MPH)	MEASURED Δ V (MPH)	SOURCE OF A,B,G	ESTIMATED Δ V (MPH)
12FYEW4	-5	28.25	39.5, 33, 28.75, 23.75, 19.2, 15	-10.6	4512	4	4	31.5	26.4	CRASH3	18.2
										CRASH2-R,M	19.6
										CRASH2A	19.7

DAMAGE COEFFICIENTS (A,B,G) TEST SUMMARY

VEHICLE

MAKE: FORD

MODEL: TORINO

YEAR:

COLLISION

SOURCE: RICSAC VOL.4, TEST 3

TYPE: 10° FRONT-REAR

OTHER OBJECT: FORD PINTO

DATA & RESULTS

CDC	PDOF	L (IN)	C_1-C_6 (IN)	D (IN)	WEIGHT (LBS)	WHEELBASE CLASS	STIFF-NESS CLASS	MEASURED V IMPACT (MPH)	MEASURED Δ V (MPH)	SOURCE OF A,B,G	ESTIMATED Δ V (MPH)
12FZEW1	0	30	2, 2, 1.5, 1.75, 2, 2.25	22	4949	4	4	21.2	9.5	CRASH3	6.2
										CRASH2-R,M	3.1
										CRASH2A	7.5

NOTE: CRASH2A result includes effect of erroneous oblique collision correction factor.

DAMAGE COEFFICIENTS (A,B,G) TEST SUMMARY

VEHICLE

MAKE: FORD

MODEL: PINTO

YEAR:

COLLISION

SOURCE: RICSAC VOL.4, TEST 3

TYPE: 10^{o} FRONT-REAR

OTHER OBJECT: FORD TORINO

DATA & RESULTS

CDC	PDOF	L (IN)	C_1-C_6 (IN)	D (IN)	WEIGHT (LBS)	WHEELBASE CLASS	STIFF-NESS CLASS	MEASURED V IMPACT (MPH)	MEASURED Δ V (MPH)	SOURCE OF A,B,G	ESTIMATED Δ V (MPH)
06BZEW1	170	30	6.5, 6.75, 5.75, 5, 3.75, 3	5	3120	2	2	0	15.8	CRASH3	9.8
										CRASH2-R,M	4.9
										CRASH2A	11.9

NOTE: CRASH2A result includes effect of erroneous oblique collision correction factor.

DAMAGE COEFFICIENTS (A,B,G) TEST SUMMARY

VEHICLE

MAKE: FORD

MODEL: TORINO

YEAR:

COLLISION

SOURCE: RICSAC VOL. 4, TEST 4

TYPE: 10^{o} FRONT-REAR

OTHER OBJECT: FORD PINTO

DATA & RESULTS

CDC	PDOF	L (IN)	C_1-C_6 (IN)	D (IN)	WEIGHT (LBS)	WHEELBASE CLASS	STIFFNESS CLASS	MEASURED V IMPACT (MPH)	MEASURED Δ V (MPH)	SOURCE OF A,B,G	ESTIMATED Δ V (MPH)
12FZEW3	0	41.5	6.3, 7.8, 9.8, 12.5, 14.8, 18.3	16.1	4980	4	4	38.7	18.7	CRASH3	15.6
										CRASH2-R	9.1
										CRASH2A	26.5
										CRASH2-M	9.7

NOTES: CRASH2-R result produced using non-collinear PDOF angles.

CRASH2A result reflects effect of erroneous oblique collision correction factor.

DAMAGE COEFFICIENTS (A,B,G) TEST SUMMARY

VEHICLE

MAKE: FORD

MODEL: PINTO

YEAR:

COLLISION

SOURCE: RICSAC VOL.4, TEST 4

TYPE: 10^{o} FRONT-REAR

OTHER OBJECT: FORD TORINO

DATA & RESULTS

CDC	PDOF	L (IN)	C_1-C_6 (IN)	D (IN)	WEIGHT (LBS)	WHEELBASE CLASS	STIFF-NESS CLASS	MEASURED V IMPACT (MPH)	MEASURED Δ V (MPH)	SOURCE OF A,B,G	ESTIMATED Δ V (MPH)
05BYEW5	170	41.8	36, 31.8, 29, 24, 19.5, 14.8	-9.1	3190	2	2	0	22.2	CRASH3	24.3
										CRASH2-M	15.1
										CRASH2A	41.4
										CRASH2-R	14.1

NOTES: CRASH2-R result produced using non-collinear PDOF angles.

CRASH2A result reflects effect of erroneous oblique collision correction factor.

DAMAGE COEFFICIENTS (A,B,G) TEST SUMMARY

VEHICLE

MAKE: FORD

MODEL: TORINO

YEAR:

COLLISION

SOURCE: RICSAC VOL. 4, TEST 5

TYPE: 10^{o} FRONT-REAR

OTHER OBJECT: HONDA CIVIC

DATA & RESULTS

CDC	PDOF	L (IN)	C_1-C_6 (IN)	D (IN)	WEIGHT (LBS)	WHEELBASE CLASS	STIFF-NESS CLASS	MEASURED V IMPACT (MPH)	MEASURED ΔV (MPH)	SOURCE OF A,B,G	ESTIMATED ΔV (MPH)
12FZEW1	0	33.5	1.4, 1.4, 2, 2.1, 2.3, 2.9	20.3	4600	4	4	39.7	16.3	CRASH3	15.2
										CRASH2-M	7.9
										CRASH2A	29.3
										CRASH2-R	8.1

NOTE: CRASH2A result reflects effect of erroneous oblique collision correction factor.

DAMAGE COEFFICIENTS (A,B,G) TEST SUMMARY

VEHICLE

MAKE: HONDA

MODEL: CIVIC

YEAR:

COLLISION

SOURCE: RICSAC VOL.4, TEST 5

TYPE: 10^{o} FRONT-REAR

OTHER OBJECT: FORD TORINO

DATA & RESULTS

CDC	PDOF	L (IN)	C_1-C_6 (IN)	D (IN)	WEIGHT (LBS)	WHEELBASE CLASS	STIFF-NESS CLASS	MEASURED V IMPACT (MPH)	MEASURED Δ V (MPH)	SOURCE OF A,B,G	ESTIMATED Δ V (MPH)
05BDEW8	170	53	36, 36.5, 31.5, 23, 13.3, 6	-1.6	2530	1	1	0	25.1	CRASH3	27.6
										CRASH2-M	15.5
										CRASH2A	57.4
										CRASH2-R	14.8

NOTE: CRASH2A result reflects effect of erroneous oblique collision correction factor.

PICKUPS

DAMAGE COEFFICIENTS (A,B,G) TEST SUMMARY

VEHICLE

MAKE: DODGE

MODEL: D-50 PICKUP

YEAR: 1979

COLLISION

SOURCE: AETL REPORT, 10/80

TYPE: 90^{o} FRONTAL

OTHER OBJECT: BARRIER

DATA & RESULTS

CDC	PDOF	L (IN)	C_1-C_6 (IN)	D (IN)	WEIGHT (LBS)	WHEELBASE CLASS	STIFF-NESS CLASS	MEASURED V IMPACT (MPH)	MEASURED Δ V (MPH)	SOURCE OF A,B,G	ESTIMATED Δ V (MPH)
12FDEW2	0	59.5	14.3, 15.9, 16.8, 14.5	0	3113	6	8	29.75	31.09	CRASH3	27.6

DAMAGE COEFFICIENTS (A,B,G) TEST SUMMARY

VEHICLE

MAKE: TOYOTA

MODEL: LONGBED PICKUP

YEAR: 1979

COLLISION

SOURCE: AETL REPORT, 10/80

TYPE: 90^{o} FRONTAL

OTHER OBJECT: BARRIER

DATA & RESULTS

CDC	PDOF	L (IN)	C_1-C_6 (IN)	D (IN)	WEIGHT (LBS)	WHEELBASE CLASS	STIFF-NESS CLASS	MEASURED V IMPACT (MPH)	MEASURED Δ V (MPH)	SOURCE OF A,B,G	ESTIMATED Δ V (MPH)
12FDEW2	0	62.2	10.8, 13.3, 13.8, 12.2	0	3129	6	8	29.55	30.03	CRASH3	25.0

DAMAGE COEFFICIENTS (A,B,G) TEST SUMMARY

VEHICLE

MAKE: CHEVROLET

MODEL: SILVERADO K20 4WD PICKUP

YEAR: 1979

COLLISION

SOURCE: AETL REPORT, 10/80

TYPE: 90^{o} FRONTAL

OTHER OBJECT: BARRIER

DATA & RESULTS

CDC	PDOF	L (IN)	C_1-C_6 (IN)	D (IN)	WEIGHT (LBS)	WHEELBASE CLASS	STIFF-NESS CLASS	MEASURED V IMPACT (MPH)	MEASURED Δ V (MPH)	SOURCE OF A,B,G	ESTIMATED Δ V (MPH)
12FDEW3	0	76	22.6, 23.2, 23.2, 22.6	0	6044	6	4 x 4	30.44	35.82	SRL-2	28.9
							4 x 4			SRL-1	24.7
							8			CRASH3	28.9
							7				36.6

DAMAGE COEFFICIENTS (A,B,G) TEST SUMMARY

VEHICLE

MAKE: FORD

MODEL: F350 CUSTOM PICKUP

YEAR: 1979

COLLISION

SOURCE: AETL REPORT 10/80

TYPE: 90^{o} FRONTAL

OTHER OBJECT: BARRIER

DATA & RESULTS

CDC	PDOF	L (IN)	C_1-C_6 (IN)	D (IN)	WEIGHT (LBS)	WHEELBASE CLASS	STIFF-NESS CLASS	MEASURED V IMPACT (MPH)	MEASURED ΔV (MPH)	SOURCE OF A,B,G	ESTIMATED ΔV (MPH)
12FDEW2	0	76.1	18.6, 19.3, 19.1, 16.2	0	5217	6	8	29.7	36.23	CRASH3	26.9

DAMAGE COEFFICIENTS (A,B,G) TEST SUMMARY

VEHICLE

MAKE: MAZDA

MODEL: B2000 PICKUP

YEAR: 1979

COLLISION

SOURCE: AETL REPORT, 10/80

TYPE: 90^{o} FRONTAL

OTHER OBJECT: BARRIER

DATA & RESULTS

CDC	PDOF	L (IN)	C_1-C_6 (IN)	D (IN)	WEIGHT (LBS)	WHEELBASE CLASS	STIFF-NESS CLASS	MEASURED V IMPACT (MPH)	MEASURED Δ V (MPH)	SOURCE OF A,B,G	ESTIMATED Δ V (MPH)
12FDEW2	0	60.5	16.5, 17.3, 17.8, 16.7	0	3184	6	8	29.73	30.58	CRASH3	29.2

DAMAGE COEFFICIENTS (A,B,G) TEST SUMMARY

VEHICLE

MAKE: DATSUN

MODEL: PICKUP

YEAR:

COLLISION

SOURCE:

TYPE: 180° REAR

OTHER OBJECT: MOVING BARRIER

DATA & RESULTS

CDC	PDOF	L (IN)	C_1-C_6 (IN)	D (IN)	WEIGHT (LBS)	WHEELBASE CLASS	STIFF-NESS CLASS	MEASURED V IMPACT (MPH)	MEASURED Δ V (MPH)	SOURCE OF A,B,G	ESTIMATED Δ V (MPH)
06BDAW3	180	64	12, 11.4, 11.7, 12, 11.7, 11.7	0	3064	3	8		15.1	CRASH3	15.5

DAMAGE COEFFICIENTS (A,B,G) TEST SUMMARY

VEHICLE

MAKE: FORD

MODEL: RANCHERO PICKUP

YEAR:

COLLISION

SOURCE:

TYPE: 180° REAR

OTHER OBJECT: MOVING BARRIER

DATA & RESULTS

CDC	PDOF	L (IN)	C_1-C_6 (IN)	D (IN)	WEIGHT (LBS)	WHEELBASE CLASS	STIFF-NESS CLASS	MEASURED V IMPACT (MPH)	MEASURED ΔV (MPH)	SOURCE OF A,B,G	ESTIMATED ΔV (MPH)
06BDAW3	180	70	13.6, 12.9, 12.9, 12.6	0	4592	5	8		15.3	CRASH3	12.6

DAMAGE COEFFICIENTS (A,B,G) TEST SUMMARY

VEHICLE

MAKE: SUBURU

MODEL: BRAT

YEAR:

COLLISION

SOURCE:

TYPE: 90^{o} FRONTAL

OTHER OBJECT: BARRIER

DATA & RESULTS

CDC	PDOF	L (IN)	C_1-C_6 (IN)	D (IN)	WEIGHT (LBS)	WHEELBASE CLASS	STIFF-NESS CLASS	MEASURED V IMPACT (MPH)	MEASURED Δ V (MPH)	SOURCE OF A,B,G	ESTIMATED Δ V (MPH)
12FDEW4	0	58	21.3, 21, 21, 20.8	0	2866	3	8	30	35	CRASH3	34.4

DAMAGE COEFFICIENTS (A,B,G) TEST SUMMARY

VEHICLE

MAKE: DODGE

MODEL: D-100 PICKUP

YEAR:

COLLISION

SOURCE:

TYPE: 90° FRONTAL

OTHER OBJECT: BARRIER

DATA & RESULTS

CDC	PDOF	L (IN)	C_1-C_6 (IN)	D (IN)	WEIGHT (LBS)	WHEELBASE CLASS	STIFF-NESS CLASS	MEASURED V IMPACT (MPH)	MEASURED Δ V (MPH)	SOURCE OF A,B,G	ESTIMATED Δ V (MPH)
12FDEW5	0	79	21.5, 21.5	0	4275	6	8		33	CRASH3	33.4
			31.9, 31.8, 31.8, 31.6, 31.6, 31.6							SRL-1	59.2

DAMAGE COEFFICIENTS (A,B,G) TEST SUMMARY

VEHICLE

MAKE: GMC

MODEL: 1500 PICKUP

YEAR:

COLLISION

SOURCE:

TYPE: 180° REAR

OTHER OBJECT: MOVING BARRIER

DATA & RESULTS

CDC	PDOF	L (IN)	$C_1 - C_6$ (IN)	D (IN)	WEIGHT (LBS)	WHEELBASE CLASS	STIFF-NESS CLASS	MEASURED V IMPACT (MPH)	MEASURED Δ V (MPH)	SOURCE OF A,B,G	ESTIMATED Δ V (MPH)
06BDAW8	180	80	10.8, 10.5, 10.7, 10.7, 10.7, 10.7	0	4186	4	8		17.1	CRASH3	13.2

DAMAGE COEFFICIENTS (A,B,G) TEST SUMMARY

VEHICLE

MAKE: DODGE

MODEL: D-100 PICKUP

YEAR:

COLLISION

SOURCE:

TYPE: 180° REAR

OTHER OBJECT: MOVING BARRIER

DATA & RESULTS

CDC	PDOF	L (IN)	$C_1 - C_6$ (IN)	D (IN)	WEIGHT (LBS)	WHEELBASE CLASS	STIFF-NESS CLASS	MEASURED V IMPACT (MPH)	MEASURED ΔV (MPH)	SOURCE OF A,B,G	ESTIMATED ΔV (MPH)
06BDAW9	180	76	16.8, 16.8, 15.6, 15.6, 15.3, 15	0	4112	4	8		14.5	CRASH3	15.8

DAMAGE COEFFICIENTS (A,B,G) TEST SUMMARY

VEHICLE

MAKE: FORD

MODEL: F-100 PICKUP

YEAR:

COLLISION

SOURCE:

TYPE: 180° REAR

OTHER OBJECT: MOVING BARRIER

DATA & RESULTS

CDC	PDOF	L (IN)	C_1-C_6 (IN)	D (IN)	WEIGHT (LBS)	WHEELBASE CLASS	STIFF-NESS CLASS	MEASURED V IMPACT (MPH)	MEASURED Δ V (MPH)	SOURCE OF A,B,G	ESTIMATED Δ V (MPH)
06BDAW5	180	76	12.8, 10.6, 10.6, 11.5	0	4407	4	8		17	CRASH3	12.6

DAMAGE COEFFICIENTS (A,B,G) TEST SUMMARY

VEHICLE

MAKE: VOLKSWAGEN

MODEL: RABBIT PICKUP

YEAR:

COLLISION

SOURCE:

TYPE: 180° REAR

OTHER OBJECT: MOVING BARRIER

DATA & RESULTS

CDC	PDOF	L (IN)	C_1-C_6 (IN)	D (IN)	WEIGHT (LBS)	WHEELBASE CLASS	STIFF-NESS CLASS	MEASURED V IMPACT (MPH)	MEASURED ΔV (MPH)	SOURCE OF A,B,G	ESTIMATED ΔV (MPH)
06BDEW8	180	63	9.125, 9.75, 9.625, 9.75, 9.75, 9.75	0	2678	6	8			CRASH3	15.6

DAMAGE COEFFICIENTS (A,B,G) TEST SUMMARY

VEHICLE

MAKE: DODGE

MODEL: D-50 PICKUP

YEAR:

COLLISION

SOURCE:

TYPE: 180^{o} REAR

OTHER OBJECT: MOVING BARRIER

DATA & RESULTS

CDC	PDOF	L (IN)	C_1-C_6 (IN)	D (IN)	WEIGHT (LBS)	WHEELBASE CLASS	STIFF-NESS CLASS	MEASURED V IMPACT (MPH)	MEASURED △ V (MPH)	SOURCE OF A,B,G	ESTIMATED △ V (MPH)
06BDEW7	180	65	13.5, 13.5, 13.375, 13.375, 13.375,13.5	0	3159	6	8			CRASH3	16.3

<u>V A N S</u>

DAMAGE COEFFICIENTS (A,B,G) TEST SUMMARY

VEHICLE

MAKE: VOLKSWAGEN

MODEL: VANAGON

YEAR: 1980

COLLISION

SOURCE:

TYPE: 180° REAR

OTHER OBJECT: MOVING BARRIER

DATA & RESULTS

CDC	PDOF	L (IN)	C_1-C_6 (IN)	D (IN)	WEIGHT (LBS)	WHEELBASE CLASS	STIFF-NESS CLASS	MEASURED V IMPACT (MPH)	MEASURED Δ V (MPH)	SOURCE OF A,B,G	ESTIMATED Δ V (MPH)
06BDAW6	180	72	6.75, 8.125, 8.75, 8.125, 8.625, 7.375	0	3912	5	7	0	15.23	CRASH3	10.9

DAMAGE COEFFICIENTS (A,B,G) TEST SUMMARY

VEHICLE

MAKE: CHEVROLET

MODEL: C20 VAN

YEAR: 1979

COLLISION

SOURCE: AETL REPORT, 10/80

TYPE: 90^{o} FRONTAL

OTHER OBJECT: BARRIER

DATA & RESULTS

CDC	PDOF	L (IN)	C_1-C_6 (IN)	D (IN)	WEIGHT (LBS)	WHEELBASE CLASS	STIFF-NESS CLASS	MEASURED V IMPACT (MPH)	MEASURED ΔV (MPH)	SOURCE OF A,B,G	ESTIMATED ΔV (MPH)
12FDEW4	0	73.5	15.7, 16.5, 16,13.8	0	5402	6	7	29.21	30.07	SRL-2	27.5

DAMAGE COEFFICIENTS (A,B,G) TEST SUMMARY

VEHICLE

MAKE: FORD

MODEL: ECONOLINE VAN

YEAR:

COLLISION

SOURCE:

TYPE: 90° FRONTAL

OTHER OBJECT: BARRIER

DATA & RESULTS

CDC	PDOF	L (IN)	C_1-C_6 (IN)	D (IN)	WEIGHT (LBS)	WHEELBASE CLASS	STIFF-NESS CLASS	MEASURED V IMPACT (MPH)	MEASURED Δ V (MPH)	SOURCE OF A,B,G	ESTIMATED Δ V (MPH)
12FDEW2	0	72	12.3, 13.1	0	4997	6	7			CRASH3	23.7
			12.3, 9.4, 10.3, 10.9, 10.6, 13.1								20.8
							8				19.3

DAMAGE COEFFICIENTS (A,B,G) TEST SUMMARY

VEHICLE

MAKE: CHEVROLET

MODEL: G10 VAN

YEAR:

COLLISION

SOURCE:

TYPE: 180° REAR

OTHER OBJECT: MOVING BARRIER

DATA & RESULTS

CDC	PDOF	L (IN)	C_1-C_6 (IN)	D (IN)	WEIGHT (LBS)	WHEELBASE CLASS	STIFF-NESS CLASS	MEASURED V IMPACT (MPH)	MEASURED Δ V (MPH)	SOURCE OF A,B,G	ESTIMATED Δ V (MPH)
06BDAW4	180	70	28.9, 29.3, 29.3, 27.5	0	4805	6	7		16.3	CRASH3	23.2

DAMAGE COEFFICIENTS (A,B,G) TEST SUMMARY

VEHICLE

MAKE: FORD

MODEL: E-100 VAN

YEAR:

COLLISION

SOURCE:

TYPE: 180° REAR

OTHER OBJECT: MOVING BARRIER

DATA & RESULTS

CDC	PDOF	L (IN)	C_1-C_6 (IN)	D (IN)	WEIGHT (LBS)	WHEELBASE CLASS	STIFF-NESS CLASS	MEASURED V IMPACT (MPH)	MEASURED ΔV (MPH)	SOURCE OF A,B,G	ESTIMATED ΔV (MPH)
06BDAW6	180	72	8.2, 8.6, 8.7, 8.7, 8.4, 8.1	0	4430	4	7		17	CRASH3	10.3

DAMAGE COEFFICIENTS (A,B,G) TEST SUMMARY

VEHICLE

MAKE: CHAMPION

MODEL: TRANS-VAN (MOTOR HOME)

YEAR: 1979

COLLISION

SOURCE: AETL REPORT, 10/80

TYPE: 90° FRONTAL

OTHER OBJECT: BARRIER

DATA & RESULTS

CDC	PDOF	L (IN)	C_1-C_6 (IN)	D (IN)	WEIGHT (LBS)	WHEELBASE CLASS	STIFF-NESS CLASS	MEASURED V IMPACT (MPH)	MEASURED Δ V (MPH)	SOURCE OF A,B,G	ESTIMATED Δ V (MPH)
12FDEW6	0	78	16.8, 19, 18.3, 14.4	0	5912	6	7	29.48	33.23	SRL-2	29.8

DAMAGE COEFFICIENTS (A,B,G) TEST SUMMARY

VEHICLE

MAKE:

MODEL: (VAN#1)

YEAR:

COLLISION

SOURCE:

TYPE: 90^{o} FRONTAL

OTHER OBJECT: BARRIER

DATA & RESULTS

CDC	PDOF	L (IN)	C_1-C_6 (IN)	D (IN)	WEIGHT (LBS)	WHEELBASE CLASS	STIFF-NESS CLASS	MEASURED V IMPACT (MPH)	MEASURED ΔV (MPH)	SOURCE OF A,B,G	ESTIMATED ΔV (MPH)
							7	25		CRASH3	20.8

DAMAGE COEFFICIENTS (A,B,G) TEST SUMMARY

VEHICLE

MAKE:

MODEL: (VAN #2)

YEAR:

COLLISION

SOURCE:

TYPE: 90^o FRONTAL

OTHER OBJECT: BARRIER

DATA & RESULTS

CDC	PDOF	L (IN)	C_1-C_6 (IN)	D (IN)	WEIGHT (LBS)	WHEELBASE CLASS	STIFF-NESS CLASS	MEASURED V IMPACT (MPH)	MEASURED Δ V (MPH)	SOURCE OF A,B,G	ESTIMATED Δ V (MPH)
12FDEW2	0	72	12.7, 11, 11.5, 11.6, 11.4, 13.9	0	4647	6	7	25		CRASH3	23.1
			12.4, 13.2, 14.2, 14.5, 13.5, 12.8								26.0

DAMAGE COEFFICIENTS (A,B,G) TEST SUMMARY

VEHICLE

MAKE:

MODEL: (VAN #3)

YEAR:

COLLISION

SOURCE:

TYPE: 90^{o} FRONTAL

OTHER OBJECT: BARRIER

DATA & RESULTS

CDC	PDOF	L (IN)	C_1-C_6 (IN)	D (IN)	WEIGHT (LBS)	WHEELBASE CLASS	STIFF-NESS CLASS	MEASURED V IMPACT (MPH)	MEASURED ΔV (MPH)	SOURCE OF A,B,G	ESTIMATED ΔV (MPH)
12FDEW2	0	72	15, 15.5, 16.3, 16.4, 15.9, 15.3	0	4654	6	7	30		CRASH3	29.5

DAMAGE COEFFICIENTS (A,B,G) TEST SUMMARY

VEHICLE

MAKE:

MODEL: (VAN #4)

YEAR:

COLLISION

SOURCE:

TYPE: 90^{o} FRONTAL

OTHER OBJECT: BARRIER

DATA & RESULTS

CDC	PDOF	L (IN)	C_1-C_6 (IN)	D (IN)	WEIGHT (LBS)	WHEELBASE CLASS	STIFF-NESS CLASS	MEASURED V IMPACT (MPH)	MEASURED Δ V (MPH)	SOURCE OF A,B,G	ESTIMATED Δ V (MPH)
12FDEW2	0	72	5.5, 5.6, 5.8, 5.7, 5.7, 5.5	0	4990	6	7	15		CRASH3	13.1

CHEVROLET CITATION

(X-BODY)

DAMAGE COEFFICIENTS (A,B,G) TEST SUMMARY

VEHICLE

MAKE: CHEVROLET

MODEL: CITATION

YEAR:

COLLISION

SOURCE:

TYPE: 90° FRONTAL

OTHER OBJECT: BARRIER

DATA & RESULTS

CDC	PDOF	L (IN)	C_1-C_6 (IN)	D (IN)	WEIGHT (LBS)	WHEELBASE CLASS	STIFF-NESS CLASS	MEASURED V IMPACT (MPH)	MEASURED Δ V (MPH)	SOURCE OF A,B,G	ESTIMATED Δ V (MPH)
12FDEW3	0	68.3	28.5, 28.5	0	3150	3	9	40		CRASH3	38.8
							4			CRASH3	37.3

DAMAGE COEFFICIENTS (A,B,G) TEST SUMMARY

VEHICLE

MAKE: CHEVROLET

MODEL: CITATION

YEAR:

COLLISION

SOURCE:

TYPE: 90° FRONTAL

OTHER OBJECT: BARRIER

DATA & RESULTS

CDC	PDOF	L (IN)	$C_1 - C_6$ (IN)	D (IN)	WEIGHT (LBS)	WHEELBASE CLASS	STIFF-NESS CLASS	MEASURED V IMPACT (MPH)	MEASURED Δ V (MPH)	SOURCE OF A,B,G	ESTIMATED Δ V (MPH)
12FDEW4	0	68.3	40.3, 40.3	0	3150	3	9	45		CRASH3	50.7
							4			CRASH3	48.6

DAMAGE COEFFICIENTS (A,B,G) TEST SUMMARY

VEHICLE

MAKE: CHEVROLET

MODEL: CITATION

YEAR:

COLLISION

SOURCE:

TYPE: 90° FRONTAL

OTHER OBJECT: BARRIER

DATA & RESULTS

CDC	PDOF	L (IN)	C_1-C_6 (IN)	D (IN)	WEIGHT (LBS)	WHEELBASE CLASS	STIFF-NESS CLASS	MEASURED V IMPACT (MPH)	MEASURED Δ V (MPH)	SOURCE OF A,B,G	ESTIMATED Δ V (MPH)
12FDEW2	0	68.3	21.3, 21.3	0	3150	3	9	35		CRASH3	31.5
							4			CRASH3	30.4
							9			SRL-2	35.9
							4			SRL-2	32.7

ASSORTED 4X4 VEHICLES

DAMAGE COEFFICIENTS (A,B,G) TEST SUMMARY

VEHICLE

MAKE: JEEP

MODEL: WAGONEER 4WD

YEAR: 1979

COLLISION

SOURCE: AETL REPORT, 10/80

TYPE: 90^{o} FRONTAL

OTHER OBJECT: BARRIER

DATA & RESULTS

CDC	PDOF	L (IN)	C_1-C_6 (IN)	D (IN)	WEIGHT (LBS)	WHEELBASE CLASS	STIFF-NESS CLASS	MEASURED V IMPACT (MPH)	MEASURED Δ V (MPH)	SOURCE OF A,B,G	ESTIMATED Δ V (MPH)
12FDEW2	0	70.3	15, 16.4, 17.5, 16.3	0	5033	5	4X4	29.71	33.99	SRL-2	21.2
							7			CRASH3	29.0
							9				26.6

DAMAGE COEFFICIENTS (A,B,G) TEST SUMMARY

VEHICLE

MAKE: INTERNATIONAL

MODEL: SCOUT

YEAR:

COLLISION

SOURCE:

TYPE: 90° FRONTAL

OTHER OBJECT: BARRIER

DATA & RESULTS

CDC	PDOF	L (IN)	C_1-C_6 (IN)	D (IN)	WEIGHT (LBS)	WHEELBASE CLASS	STIFF-NESS CLASS	MEASURED V IMPACT (MPH)	MEASURED Δ V (MPH)	SOURCE OF A,B,G	ESTIMATED Δ V (MPH)
12FDAW8	0	70	14, 14	0	4257	4	9	29.8		CRASH3	21.0
							4				20.4
							8				23.9
							7				27.4

DAMAGE COEFFICIENTS (A,B,G) TEST SUMMARY

VEHICLE

MAKE: CHEVROLET

MODEL: BLAZER

YEAR:

COLLISION

SOURCE:

TYPE: 90° FRONTAL

OTHER OBJECT: BARRIER

DATA & RESULTS

CDC	PDOF	L (IN)	C_1-C_6 (IN)	D (IN)	WEIGHT (LBS)	WHEELBASE CLASS	STIFF-NESS CLASS	MEASURED V IMPACT (MPH)	MEASURED ΔV (MPH)	SOURCE OF A,B,G	ESTIMATED ΔV (MPH)
12FDAW2	0	70	17, 18	0	5671	4	9	29.5		CRASH3	20.9
							4				20.2
							8				23.8
							7				28.6

DAMAGE COEFFICIENTS (A,B,G) TEST SUMMARY

VEHICLE

MAKE: JEEP

MODEL: HONCHO PICKUP

YEAR: 1980

COLLISION

SOURCE:

TYPE: OBLIQUE FRONTAL - 30^{o}

OTHER OBJECT: BARRIER

DATA & RESULTS

CDC	PDOF	L (IN)	C_1-C_6 (IN)	D (IN)	WEIGHT (LBS)	WHEELBASE CLASS	STIFF-NESS CLASS	MEASURED V IMPACT (MPH)	MEASURED Δ V (MPH)	SOURCE OF A,B,G	ESTIMATED Δ V (MPH)
01FZEW4	17.5	62	6.25, 7.75, 10.25, 16.75, 21.25, 25.75	0	5100	6	7	29.53	30.61	CRASH3	24.3
							4X4			SRL-2	20.5
							4X4			SRL-1	17.9
							9			CRASH3	22.9

DAMAGE COEFFICIENTS (A,B,G) TEST SUMMARY

VEHICLE

MAKE: DATSUN

MODEL: 4WD PICKUP

YEAR: 1980

COLLISION

SOURCE:

TYPE: OBLIQUE FRONTAL - 30°

OTHER OBJECT: BARRIER

DATA & RESULTS

CDC	PDOF	L (IN)	C_1-C_6 (IN)	D (IN)	WEIGHT (LBS)	WHEELBASE CLASS	STIFF-NESS CLASS	MEASURED V IMPACT (MPH)	MEASURED ΔV (MPH)	SOURCE OF A,B,G	ESTIMATED ΔV (MPH)
01FZEW5	17.5	55	0, 5.5, 11.25, 16, 22, 27.5	0	3563	3	7	29.73	31.47	CRASH3	27.8
							4X4			SRL-2	23.1
							4X4			SRL-1	20.1
							9			CRASH3	26.0

DAMAGE COEFFICIENTS (A,B,G) TEST SUMMARY

VEHICLE

MAKE: JEEP

MODEL: CJ5

YEAR:

COLLISION

SOURCE:

TYPE: 180° REAR

OTHER OBJECT: MOVING BARRIER

DATA & RESULTS

CDC	PDOF	L (IN)	C_1-C_6 (IN)	D (IN)	WEIGHT (LBS)	WHEELBASE CLASS	STIFF-NESS CLASS	MEASURED V IMPACT (MPH)	MEASURED Δ V (MPH)	SOURCE OF A,B,G	ESTIMATED Δ V (MPH)
06BDAW3	180	58	5.3, 4.8, 4.8, 5	0	3401	4	7		15.1	CRASH3	8.2
							8				10.0

<u>1980 ASSORTED CARS</u>

DAMAGE COEFFICIENTS (A,B,G) TEST SUMMARY

VEHICLE

MAKE: MAZDA

MODEL: 626

YEAR: 1980

COLLISION

SOURCE:

TYPE: 90° FRONTAL

OTHER OBJECT: BARRIER

DATA & RESULTS

CDC	PDOF	L (IN)	C_1-C_6 (IN)	D (IN)	WEIGHT (LBS)	WHEELBASE CLASS	STIFFNESS CLASS	MEASURED V IMPACT (MPH)	MEASURED ΔV (MPH)	SOURCE OF A,B,G	ESTIMATED ΔV (MPH)
12FDEW3	0	59.4	24.8, 24.9, 25.2, 25.5	0	3066	2	2	35.2	41.8	CRASH3	31.8
							1				33.6
							3				35.8

DAMAGE COEFFICIENTS (A,B,G) TEST SUMMARY

VEHICLE

MAKE: DATSUN

MODEL: 200SX

YEAR: 1980

COLLISION

SOURCE:

TYPE: 90^{o} FRONTAL

OTHER OBJECT: BARRIER

DATA & RESULTS

CDC	PDOF	L (IN)	C_1-C_6 (IN)	D (IN)	WEIGHT (LBS)	WHEELBASE CLASS	STIFF-NESS CLASS	MEASURED V IMPACT (MPH)	MEASURED Δ V (MPH)	SOURCE OF A,B,G	ESTIMATED Δ V (MPH)
12FDEW3	0	59.6	24.6, 25.3, 25.1, 24.2	0	3083	1	1	34.1	38.9	CRASH3	33.4
							2				31.8

DAMAGE COEFFICIENTS (A,B,G) TEST SUMMARY

VEHICLE

MAKE: AUDI

MODEL: 4000

YEAR: 1980

COLLISION

SOURCE:

TYPE: 90° FRONTAL

OTHER OBJECT: BARRIER

DATA & RESULTS

CDC	PDOF	L (IN)	C_1-C_6 (IN)	D (IN)	WEIGHT (LBS)	WHEELBASE CLASS	STIFF-NESS CLASS	MEASURED V IMPACT (MPH)	MEASURED Δ V (MPH)	SOURCE OF A,B,G	ESTIMATED Δ V (MPH)
12FDEW3	0	60.8	23.5, 23.7, 23.3, 22.6	0	2836	2	2			CRASH3	31.6
							1				33.4
							3				35.5

DAMAGE COEFFICIENTS (A,B,G) TEST SUMMARY

VEHICLE

MAKE: VOLKSWAGEN

MODEL: RABBIT

YEAR: 1980

COLLISION

SOURCE:

TYPE: 90^{o} FRONTAL

OTHER OBJECT: BARRIER

DATA & RESULTS

CDC	PDOF	L (IN)	C_1-C_6 (IN)	D (IN)	WEIGHT (LBS)	WHEELBASE CLASS	STIFFNESS CLASS	MEASURED V IMPACT (MPH)	MEASURED ΔV (MPH)	SOURCE OF A,B,G	ESTIMATED ΔV (MPH)
12FDEW3	0	58.6	22.3, 22.9, 22.9, 22.6	0	2767	1	1	34.9	39.8	CRASH3	32.5
						2	2				30.7

DAMAGE COEFFICIENTS (A,B,G) TEST SUMMARY

VEHICLE

MAKE: FIAT

MODEL: STRADA

YEAR: 1980

COLLISION

SOURCE:

TYPE: 90^{o} FRONTAL

OTHER OBJECT: BARRIER

DATA & RESULTS

CDC	PDOF	L (IN)	C_1-C_6 (IN)	D (IN)	WEIGHT (LBS)	WHEELBASE CLASS	STIFF-NESS CLASS	MEASURED V IMPACT (MPH)	MEASURED △ V (MPH)	SOURCE OF A,B,G	ESTIMATED △ V (MPH)
12FDEW4	0	59.4	28, 29.1, 29.1, 28.2	0	2707	2	2	34.8	40.3	CRASH3	37.8
						1	1				39.9
						3	3				42.6

DAMAGE COEFFICIENTS (A,B,G) TEST SUMMARY

VEHICLE

MAKE: CHEVROLET

MODEL: CHEVETTE

YEAR: 1980

COLLISION

SOURCE:

TYPE: 90° FRONTAL

OTHER OBJECT: BARRIER

DATA & RESULTS

CDC	PDOF	L (IN)	C_1-C_6 (IN)	D (IN)	WEIGHT (LBS)	WHEELBASE CLASS	STIFF-NESS CLASS	MEASURED V IMPACT (MPH)	MEASURED Δ V (MPH)	SOURCE OF A,B,G	ESTIMATED Δ V (MPH)
12FDEW3	0	55.6	23, 24.3, 24.2, 22.9	0	2641	1	1	35.2	38.2	CRASH3	33.6
						2	2				31.8

DAMAGE COEFFICIENTS (A,B,G) TEST SUMMARY

VEHICLE

MAKE: SUBARU

MODEL: GLF

YEAR: 1980

COLLISION

SOURCE:

TYPE: 90° FRONTAL

OTHER OBJECT: BARRIER

DATA & RESULTS

CDC	PDOF	L (IN)	C_1-C_6 (IN)	D (IN)	WEIGHT (LBS)	WHEELBASE CLASS	STIFF-NESS CLASS	MEASURED V IMPACT (MPH)	MEASURED Δ V (MPH)	SOURCE OF A,B,G	ESTIMATED Δ V (MPH)
12FDEW3	0	57.2	22.8, 22.8, 22.7, 22.3	0	2618	1	1	35.0	38.5	CRASH3	32.9
						2	2				31.1
						3	3				35.0

DAMAGE COEFFICIENTS (A,B,G) TEST SUMMARY

VEHICLE

MAKE: LINCOLN

MODEL:

YEAR: 1980

COLLISION

SOURCE:

TYPE: 90° FRONTAL

OTHER OBJECT: BARRIER

DATA & RESULTS

CDC	PDOF	L (IN)	C_1-C_6 (IN)	D (IN)	WEIGHT (LBS)	WHEELBASE CLASS	STIFFNESS CLASS	MEASURED V IMPACT (MPH)	MEASURED ΔV (MPH)	SOURCE OF A,B,G	ESTIMATED ΔV (MPH)
12FDEW2	0	70	26.7, 27.7, 26.3, 26.3, 27.7, 26.7	0	4565	5	5	29.8	33.3	CRASH3	30.1
						6	6				30.1
						4	4				30.1

DAMAGE COEFFICIENTS (A,B,G) TEST SUMMARY

VEHICLE

MAKE: OLDSMOBILE

MODEL: 98

YEAR: 1980

COLLISION

SOURCE:

TYPE: 90° FRONTAL

OTHER OBJECT: BARRIER

DATA & RESULTS

CDC	PDOF	L (IN)	C_1-C_6 (IN)	D (IN)	WEIGHT (LBS)	WHEELBASE CLASS	STIFF-NESS CLASS	MEASURED V IMPACT (MPH)	MEASURED ΔV (MPH)	SOURCE OF A,B,G	ESTIMATED ΔV (MPH)
12FDEW3	0	69.6	23.4, 24.7, 23.2, 27.6, 25.5, 25.1	0	4492	5	5	29.8	31.2	CRASH3	28.6
						4	4				28.8

DAMAGE COEFFICIENTS (A,B,G) TEST SUMMARY

VEHICLE

MAKE: MERCURY

MODEL: COUGAR

YEAR: 1980

COLLISION

SOURCE:

TYPE: 180° REAR

OTHER OBJECT: MOVING BARRIER

DATA & RESULTS

CDC	PDOF	L (IN)	C_1-C_6 (IN)	D (IN)	WEIGHT (LBS)	WHEELBASE CLASS	STIFFNESS CLASS	MEASURED V IMPACT (MPH)	MEASURED Δ V (MPH)	SOURCE OF A,B,G	ESTIMATED Δ V (MPH)
06BDEW1	180	67.8	7.9, 8.2, 9.0, 9.4, 9.2, 8.9	0	3715	4	4		21.8	CRASH3	14.3
						3	3				13.1
						5	5				11.9

DAMAGE COEFFICIENTS (A,B,G) TEST SUMMARY

VEHICLE

MAKE: HONDA

MODEL: PRELUDE

YEAR: 1980

COLLISION

SOURCE:

TYPE: 180° REAR

OTHER OBJECT: MOVING BARRIER

DATA & RESULTS

CDC	PDOF	L (IN)	C_1-C_6 (IN)	D (IN)	WEIGHT (LBS)	WHEELBASE CLASS	STIFF-NESS CLASS	MEASURED V IMPACT (MPH)	MEASURED Δ V (MPH)	SOURCE OF A,B,G	ESTIMATED Δ V (MPH)
06BDEW2	180	61	17.4, 17.4, 17.6, 17.4	0	2561	1	1		23.5	CRASH3	22.5
						2	2				23.2

DAMAGE COEFFICIENTS (A,B,G) TEST SUMMARY

VEHICLE

MAKE: RENAULT

MODEL: LE CAR

YEAR: 1980

COLLISION

SOURCE:

TYPE: 180° REAR

OTHER OBJECT: MOVING BARRIER

DATA & RESULTS

CDC	PDOF	L (IN)	$C_1 - C_6$ (IN)	D (IN)	WEIGHT (LBS)	WHEELBASE CLASS	STIFF-NESS CLASS	MEASURED V IMPACT (MPH)	MEASURED ΔV (MPH)	SOURCE OF A,B,G	ESTIMATED ΔV (MPH)
06BDEW2	180	55	14, 14.5, 14.7, 15.2	0	2271	2	2		22	CRASH3	21.4
						1	1				20.7
						3	3				22.0

DAMAGE COEFFICIENTS (A,B,G) TEST SUMMARY

VEHICLE

MAKE: PLYMOUTH

MODEL: GRAND FURY

YEAR: 1980

COLLISION

SOURCE:

TYPE: 180° REAR

OTHER OBJECT: MOVING BARRIER

DATA & RESULTS

CDC	PDOF	L (IN)	C_1-C_6 (IN)	D (IN)	WEIGHT (LBS)	WHEELBASE CLASS	STIFF-NESS CLASS	MEASURED V IMPACT (MPH)	MEASURED Δ V (MPH)	SOURCE OF A,B,G	ESTIMATED Δ V (MPH)
06BDEW2	180	68	14.1, 14.5, 14.5, 14.5, 14.2, 14.4	0	4227	5	5		16.1	CRASH3	15.4
						4	4				14.9

DAMAGE COEFFICIENTS (A,B,G) TEST SUMMARY

VEHICLE

MAKE: DODGE

MODEL: COLT WAGON

YEAR: 1980

COLLISION

SOURCE:

TYPE: 180° REAR

OTHER OBJECT: MOVING BARRIER

DATA & RESULTS

CDC	PDOF	L (IN)	C_1-C_6 (IN)	D (IN)	WEIGHT (LBS)	WHEELBASE CLASS	STIFF-NESS CLASS	MEASURED V IMPACT (MPH)	MEASURED △ V (MPH)	SOURCE OF A,B,G	ESTIMATED △ V (MPH)
06BDEW1	180	60.1	9.3, 10.3, 10.4, 9.5	0	3354	1	1		18	CRASH3	13.4
						2	2				13.8
						3	3				14.2

OTHER DAMAGE RUNS

DAMAGE COEFFICIENTS (A,B,G) TEST SUMMARY

VEHICLE

MAKE: DATSUN

MODEL: F10 STATION WAGON

YEAR:

COLLISION

SOURCE:

TYPE: 90° FRONTAL

OTHER OBJECT: BARRIER

DATA & RESULTS

CDC	PDOF	L (IN)	C_1-C_6 (IN)	D (IN)	WEIGHT (LBS)	WHEELBASE CLASS	STIFF-NESS CLASS	MEASURED V IMPACT (MPH)	MEASURED ΔV (MPH)	SOURCE OF A,B,G	ESTIMATED ΔV (MPH)
12FDAW5	0	58	17.5, 17.5	0	2332	1	1		30	CRASH3	28.9

DAMAGE COEFFICIENTS (A,B,G) TEST SUMMARY

VEHICLE

MAKE:

MODEL: (VEHICLE 1)

YEAR:

COLLISION

SOURCE: SCHNEIDER CENTRAL COLLISION ABB.4, CRASH3 USER'S GUIDE

TYPE: 90° FRONT-SIDE

OTHER OBJECT: VEHICLE 2

DATA & RESULTS

CDC	PDOF	L (IN)	C_1–C_6 (IN)	D (IN)	WEIGHT (LBS)	WHEELBASE CLASS	STIFF-NESS CLASS	MEASURED V IMPACT (MPH)	MEASURED Δ V (MPH)	SOURCE OF A,B,G	ESTIMATED Δ V (MPH)
12FDEW1	0	75	3.1, 3.1	0	3461	4	4	~24	~8	CRASH3	13.9
										CRASH2A	8.1

DAMAGE COEFFICIENTS (A,B,G) TEST SUMMARY

VEHICLE

MAKE:

MODEL: (VEHICLE 2)

YEAR:

COLLISION

SOURCE: SCHNEIDER CENTRAL COLLISION ABB.4, CRASH3 USER'S GUIDE

TYPE: 90° FRONT-SIDE

OTHER OBJECT: VEHICLE 1

DATA & RESULTS

CDC	PDOF	L (IN)	C_1-C_6 (IN)	D (IN)	WEIGHT (LBS)	WHEELBASE CLASS	STIFF-NESS CLASS	MEASURED V IMPACT (MPH)	MEASURED Δ V (MPH)	SOURCE OF A,B,G	ESTIMATED Δ V (MPH)
03RPEW2	90	75	8.7, 8.7	0	1730.6	1	1	0	~16	CRASH3	27.9
										CRASH2A	16.2

DAMAGE COEFFICIENTS (A,B,G) TEST SUMMARY

VEHICLE

MAKE:

MODEL: (VEHICLE 1)

YEAR:

COLLISION

SOURCE: SCHNEIDER CENTRAL COLLISION ABB.5, CRASH3 USER'S GUIDE

TYPE: 90° FRONT-SIDE

OTHER OBJECT: VEHICLE 2

DATA & RESULTS

CDC	PDOF	L (IN)	C_1-C_6 (IN)	D (IN)	WEIGHT (LBS)	WHEELBASE CLASS	STIFF-NESS CLASS	MEASURED V IMPACT (MPH)	MEASURED ΔV (MPH)	SOURCE OF A,B,G	ESTIMATED ΔV (MPH)
12FDEW1	0	69	8.7, 8.7	0	1730.6	1	1	~18	~12	CRASH3	18.6
										CRASH2A	17.6

DAMAGE COEFFICIENTS (A,B,G) TEST SUMMARY

VEHICLE

MAKE:

MODEL: (VEHICLE 2)

YEAR:

COLLISION

SOURCE: SCHNEIDER CENTRAL COLLISION ABB.5, CRASH3 USER'S GUIDE

TYPE: 90^{o} FRONT-SIDE

OTHER OBJECT: VEHICLE 1

DATA & RESULTS

CDC	PDOF	L (IN)	C_1-C_6 (IN)	D (IN)	WEIGHT (LBS)	WHEELBASE CLASS	STIFF-NESS CLASS	MEASURED V IMPACT (MPH)	MEASURED Δ V (MPH)	SOURCE OF A,B,G	ESTIMATED Δ V (MPH)
03RPEW1	90	59	6.7, 6.7	0	3461.2	4	4	0	~6	CRASH3	9.3
										CRASH2A	8.8