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CALSPAN/CHRYSLER RESEARCH SAFETY VEHICLE PHASE III FINAL TECHNICAL REPORT

Volume I: Executive Summary

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FINAL REPORT

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16. Abstract
In Phase III of the RSV program, the Phase II design of subsystems and components was refined and adapted to exemplify mass production techniques. This report summarizes the integration of the various elements into a coordinated design from which ten vehicles were fabricated for test and evaluation by others in Phase IV. The five-passenger family car is designed to be fabricated by mass production techniques from materials chosen to minimize energy content, rare mineral requirements, and facilitate recycling for recovery and reuse. Using a combination of mathematical modeling on the computer with static and dynamic testing, design issues that remained at the completion of Phase II were resolved; validation tests were conducted to demonstrate performance resulting from these design improvements; and the results were incorporated in the final design. Additional investigations defined emissions and fuel economy, documented the degree of RSV compliance with current Federal Motor Vehicle Standards, and studied the effect of the RSV design on collision repair, producibility, and cost of program goals. All RSVs built for evaluation in Phase IV were delivered to NHTSA by 8 May 1979. Tests confirmed the successful achievement.

17. Key Words
Automobile Handling, Economy Safety, Crashworthiness Occupant Restraints, Pedestrian Safety, Bumpers, Structure, Chassis, Body, Design Styling

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METRIC CONVERSION FACTORS

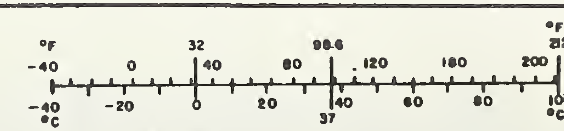
Approximate Conversions to Metric Measures

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



FOREWORD

The first phase of the Research Safety Vehicle (RSV) program was initiated at Calspan in January 1974; Phase II began in July 1975. The third phase of the Calspan RSV program was started on 26 January 1977 and is currently scheduled for completion on 31 May 1980. It is the subject of this report. As in the earlier work, Chrysler Corporation has been the major subcontractor. They have been responsible for most of the vehicle body and chassis design as well as the high degree of mass production technology that has been incorporated in the methods for fabricating the components. This final technical report has been prepared by the combined efforts of program staff members at both Calspan and Chrysler. The information included has previously appeared in correspondence, internal memos, progress reports, and various other documents cited in the references. It is the intention of the editor to combine that information into a comprehensive summary referencing other documents that more completely recount the work accomplished during the third phase of the RSV program which culminated in the ten final vehicles built for testing during Phase IV.

The final report on the RSV Phase III program is presented in two volumes. This Executive Summary comprises the first volume. It is drawn largely from Reference 27 with modifications and additions. Volume II presents the technical discussion of the results of the work undertaken during the third phase of the program. The Contract Technical Manager for the sponsor, DOT/NHTSA, is Frank G. Richardson. The contents of this publication reflect the views of the Calspan and Chrysler RSV staffs and are not necessarily those of the National Highway Traffic Safety Administration.

G. J. Fabian
RSV Program Manager

ACKNOWLEDGMENTS

Many people and organizations have contributed to the RSV program. Calspan is the prime contractor, but a large measure of the effort was undertaken by Chrysler Corporation. Calspan led in overall program direction, being primarily involved in the background investigations that led to the design specification, occupant restraint system design, component and vehicle evaluation testing as well as being instrumental in crashworthiness development. Chrysler's activities included structural design of the body and chassis to meet performance goals within the anticipated capabilities of future manufacturing technology, pedestrian protection, and engine and driveline installation, fuel economy, emissions, and styling. Subcontractors and suppliers to this project span the automotive industry, but the following organizations should be recognized for their support: Allied Chemical, Bendix, Cibie, Creative Industries, Davidson Rubber, Goodyear, Great Lakes Steel, Hexcel, Modern Engineering Services, Motor Insurance Repair Research Centre, Roblin Industries, St. Gobian, Sheller-Globe, Takata Kojyo, and Thiokol. Finally, and most importantly, the contributions of Frank G. Richardson, NHTSA Program Technical Monitor, are gratefully acknowledged. Volume II identifies in more detail the contribution of the various supporting organizations.

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1.0 INTRODUCTION

The overall objective of the National Highway Traffic Safety Administration's Research Safety Vehicle (RSV) program is to develop technological data applicable to automotive safety requirements for the mid 1980s and, in addition, to evaluate the compatibility of these safety goals with environmental policies, energy utilization and consumer economic considerations for that time period. To assist NHTSA in obtaining information appropriate for formulating meaningful automotive standards for that era, a multi-phase research program was undertaken to develop a light weight, advanced safety vehicle (RSV) suitable for family transportation. Current regulations were not to be constraint on RSV design; alternative safety features were to be explored. The design was to be compatible with mass production techniques, fuel economy and emissions requirements for the eighties. The RSV was to be constructed of readily available materials, to be easily recyclable and also require minimial energy in manufacture; it was to have reasonable initial and operating costs, as well as good consumer acceptance. Most importantly, it must provide a high level of safety for its passengers, occupants of other vehicles, and pedestrians.

The car designed to meet these goals, fabricated for testing during the final fourth phase and representing the end product of a six-year Calspan/Chrysler research program is shown in Figures 1 through 4. All test vehicles now have been built and delivered. Testing of these vehicles by others in Phase IV has largely been accomplished. This reports deals with Phase III activities, but results of those Phase IV tests are summarized in Section 15 of Volume II and have been mentioned elsewhere in the text where needed to complete the discussion.

While a broad spectrum of data went into the evolution of the RSV, there obviously had to be some constraints. The most important of these concerned program size and timing. Since actual production and sale of the automobiles was not contemplated, funds and scope were significantly less

Figure 1. Calspan/Chrysler RSV

Figure 2. Calspan/Chrysler RSV

Figure 3. Calspan/Chrysler RSV

Figure 4. Calspan/Chrysler RSV

than would be invested by an automotive company to develop a new production vehicle. Selectivity was necessary in choosing the areas where research and development could be most beneficial. Final development activities were directed primarily toward crash safety systems with minimum concern for refinement of basic automotive systems common to current cars. For instance, expense of developing advanced emission systems for 1985 was not incurred; instead, current systems were accepted. Similarly, the original width of the Simca base car from which it was developed was maintained in the RSV for reasons of cost effectiveness despite the interior space occupied by the energy absorbing door trim panels. In fact, the choice of developing the RSV from a current mass produced vehicle, while providing a reliable basis for production aspects, imposed design and performance limitations on the final design. Timing was, of course, important. To be effective as an aid to defining 1985 safety requirements, the RSV program had to be completed sufficiently early to permit reasonable lead time for rule making if the production cars were to be expected to include similar features. Consequently, in many instances, where an entirely new concept or direction was involved, development could only be carried to a feasibility demonstration level; while the RSV points the way, additional research, development and testing will be required before new standards could be implemented in those areas.

Previous publications have discussed the many aspects of the program (References 1 and 2). A Phase II status report, as well as reviews of technical aspects of the design were presented at the Sixth ESV Conference (References 3 through 9). More recent activities in Phase III have been covered in reports and papers (References 10 through 27). That documentation will be referenced below in the brief review of the earlier work that is included to provide continuity and an appropriate frame of reference for the subsequent description of the final Calspan/Chrysler RSV.

2.0 PROGRAM DEVELOPMENT

In the first phase of the program, initiated in January 1974, an analysis of the environment in which the vehicle is to operate in the mid 1980s was developed through investigations of trends of automotive usage, accident data, population growth, and the prediction of economic and resource status. From that postulated environment was developed a definition of vehicle characteristics suitable for 1985, including vehicle performance specifications and preliminary design concepts. A review of accident statistics indicated priorities to be placed on crashworthiness (occupant protection) and pedestrian protection. Economic and environmental constraints imposed limits on vehicle weight and power.[1*]

On the basis of the automotive usage trend analysis and the continuing scarcity of fuel, as well as the other considerations, the initial vehicle was defined as a 2700 pound sedan (Figure 5) having a capacity suitable for normal family use and fuel economy approaching 30 miles per gallon. Recycling of materials to conserve vital mineral content as well as to minimize the energy required for the vehicle fabrication also was a design objective.

The Phase I study included analysis of the distribution of traffic fatalities in 1972. Some of the results are shown in Figures 6 and 7. The occupants of passenger cars represent 62 percent of the total. Pedestrians struck by vehicles make up another 19 percent. Reduction of fatalities and serious injuries in these categories would appreciably reduce the cost of transportation. In addition, a preponderous portion of pedestrian injuries arises from vehicle frontal impacts. Significant reductions in the pedestrian fatalities might be achieved by a new approach to the design of the front of the car. Such accident statistics in combination with a wide variety of background factors led to the RSV crashworthiness goals summarized in Figure 8.

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*Superscripts denote references listed at the end of the report.

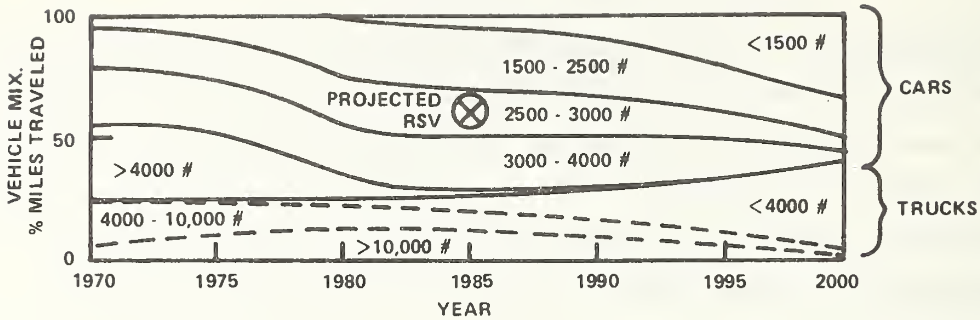

Figure 5 PROJECTED VEHICLE MIX

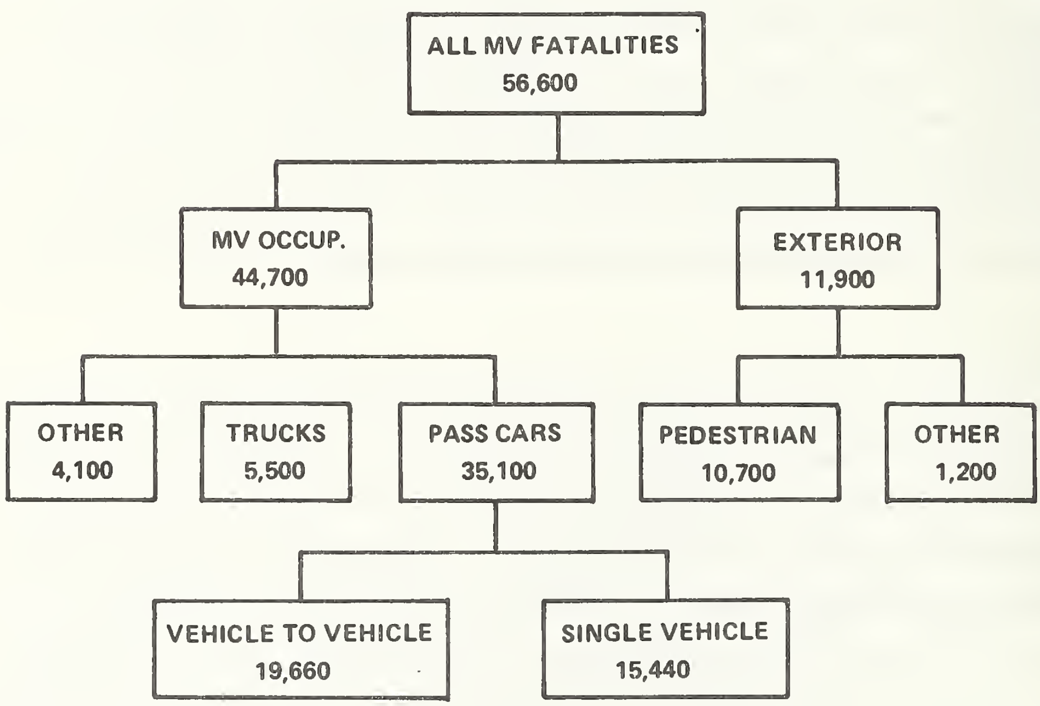

Figure 6 DISTRIBUTION OF U.S. TRAFFIC FATALITIES

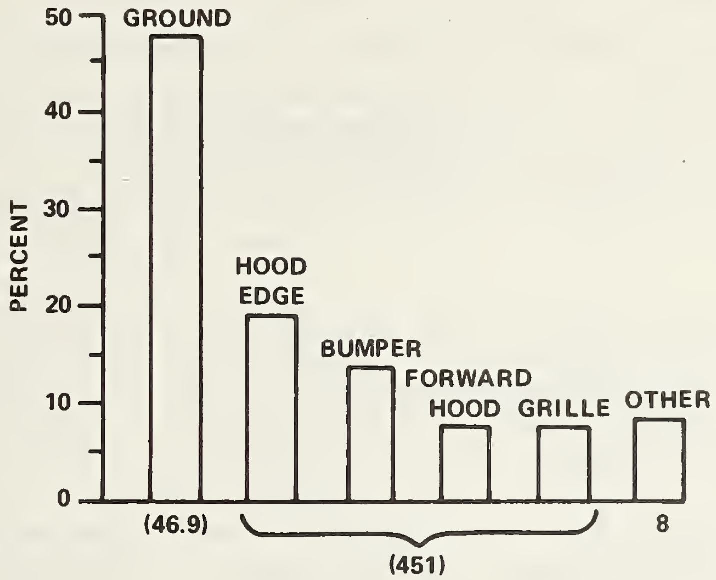

Figure 7 INJURY PRODUCING ELEMENTS - ALL PEDESTRIAN INJURIES IN FRONT IMPACTS WITH FULL SIZE AMERICAN AUTOMOBILES

	IMPACT OBJECT	CONFIGURATION	IMPACT SPEED (MPH)		COMMENTS
			GOAL	MINIMUM	
FRONT	FIXED FLAT BARRIER	0^{o} TO 45^{o}	50	40	INJURY CRITERIA FRONT SEAT OCCUPANTS
	FIXED POLE BARRIER	CENTER IMPACT	50	40	INJURY CRITERIA FRONT SEAT OCCUPANTS
	FIXED FLAT BARRIER	0^{o}	35	30	INJURY CRITERIA ALL POSITIONS, EGRESS DOORS
	FIXED FLAT BARRIER	0^{o}	25	20	MAXIMUM BARRIER FORCE 60,000 lbs.
	RSV	50% OFFSET	50*	40*	INJURY CRITERIA
	RSV	CENTER IMPACT	50*	40*	INJURY CRITERIA FRONT SEAT OCCUPANTS
SIDE	RSV	0^{o} TO 45^{o}	45	40	INJURY CRITERIA OCCUPANTS STRUCK SIDE
REAR	RSV	0^{o}	50	45	INJURY CRITERIA ALL OCCUPANTS

*SPEED FOR EACH CAR

Figure 8 RSV CRASH PERFORMANCE SPECIFICATIONS

Many other goals were established for a variety of other RSV capabilities. The RSV specification developed in Phase I is included as the appendix of Volume II with parameters measured on the final RSV for comparison. Cost/benefit studies were not performed at that time on specific features because actual on-the-road experience was deemed to be required to accurately assess their value.

Since it was felt that the mass production capability of the vehicle was of parmount importance to the credibility of the data, the approach taken utilized a Chrysler Simca 1307/1308 as the base vehicle which was subsequently modified to achieve the design goals. Although bringing with it certain design limitations, the base vehicle provides dimensional, weight and handling characteristics that approximate the Phase I RSV specifications. In addition, the Simca 1308 manufacturing facilities furnish a realistic basis for estimating the effects on cost and producibility of design or process changes attendent to the achievement of RSV safety, emissions, and efficiency goals. Environmental (emissions) constraints were observed along with fuel efficiency performance.

Phase II activities were directed toward some refinement of the RSV specifications, thoroughly testing the Simca 1308 to determine the base car performance, preliminary design of the crash safety elements and building and testing of prototypes to establish the capabilities of the design to meet crashworthiness goals.[2] Figure 9 illustrates the methodology adopted to bring the various vehicle elements into harmony. Particularly to be noted is the prominent part played by computer simulation which makes possible exploring design tradeoffs and compromises. Careful attention has been paid throughout the program to important considerations such as producibility, costs, and other "real life" factors to assure credibility of the results and their applicability to the 1985 time frame. Economics of the design were addressed. Consumer costs (retail prices) were established based on an assumed annual production of 300,000 units. Research and development costs, materials, facilities, and production tooling costs were also assessed.

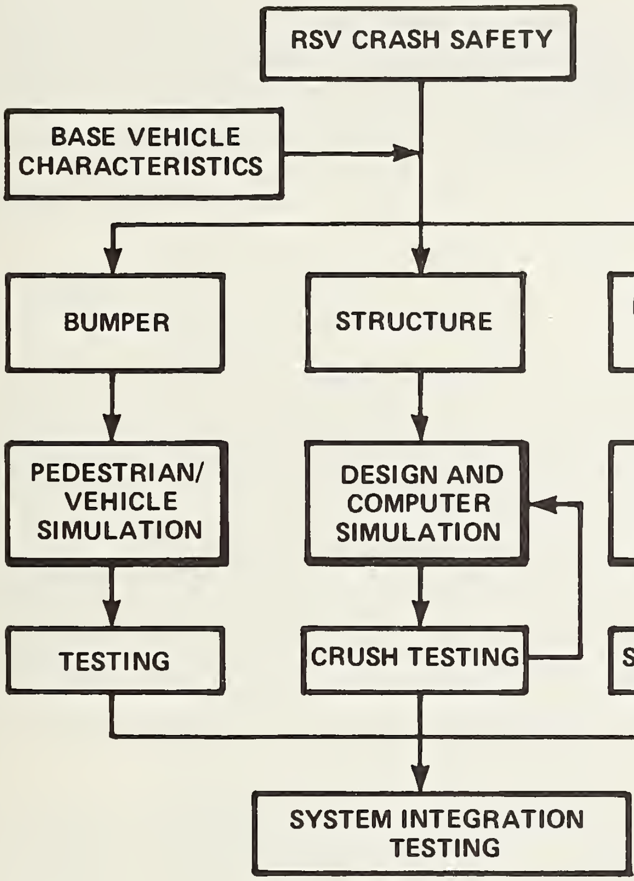

Figure 9 RSV CRASH SAFETY ACTIVITY

Phase III included not only the refinement and testing of the areas addressed in Phase II, but also considered additional characteristics not previously covered, such as durability, handling, acceleration, limited emissions control development, collision repairability, and compliance with Federal Motor Vehicle Safety Standards.

3.0 RSV FINAL DESIGN

Before discussing Phase III test results to identify the performance achieved with the Calspan/Chrysler RSV, it is appropriate to first review the features of this design.[26] A synopsis of many of the features of the RSV is shown in Figure 10.

3.1 Styling

Although the RSV resembles the Simca 1308 from which it was derived, the shape forward of the windshield is all new and the wheel base almost three inches longer. In addition, the RSV has a new rear bumper and hatch lid. Wind tunnel testing led to the rounded front shape that is also beneficial for pedestrian impact protection. Other aerodynamic effects led to reduced size of the cooling air inlets, lower front end air dam, addition of front wheel flares, rear hatch lid spoiler, and smooth wheel covers, as well as removal of the rear segment of the drip rail (Figures 1 through 4).

Interior appearance also is similar to the Simca except for items needed to provide occupant protection in the attempt to realize the high speed impact goals (Figures 11, 12 and 13). Most noticeable among these changes are the thicker door trim pads with enclosed aluminum honeycomb energy absorbers for occupant protection during side impacts (Figure 14). The internal width of the RSV is, in fact, that of the Simca base car minus the space taken up by the additional energy absorbing padding on the sides. A decision was made for Phase III to proceed with the design and fabrication of the RSV on that basis rather than to spend the additional money required to provide the internal room needed to comfortably seat three people side-by-side. Energy absorbing foam attenuates head contact forces in side impacts. Aluminum honeycomb material reduces forces from knee impacts during frontal crashes (Figure 15). "See-through" head restraints are provided for front seat passengers both for improved driver visibility and for a feeling of added interior roominess. Automatic restraint systems, described later, are also major factors in the interior appearance.

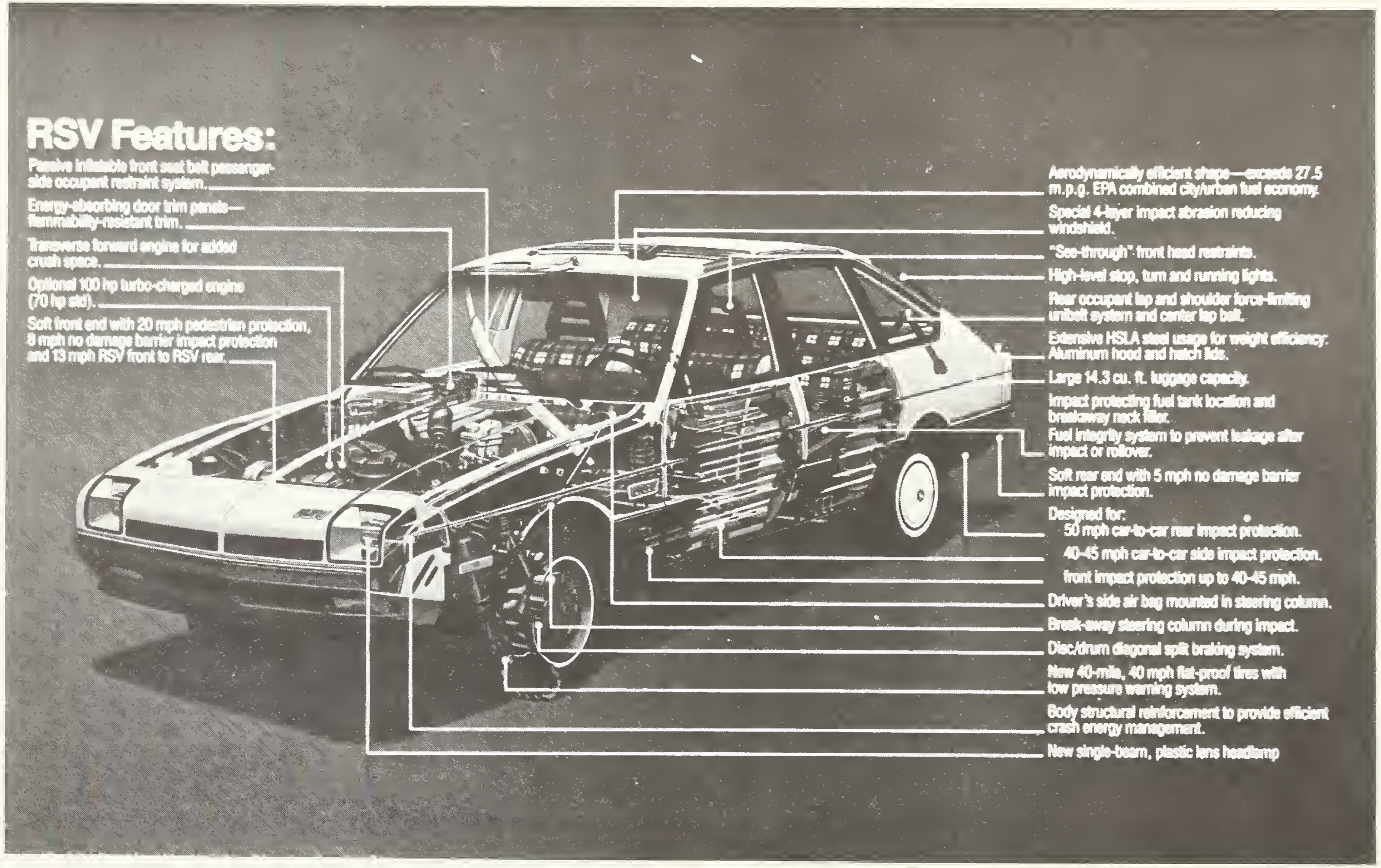

Figure 10. RSV Features

Figure 11. RSV Driver Air Bag and Instrument Panel

Figure 12. RSV Passenger Air Belt and Knee Blocker

Figure 13. RSV Rear Interior

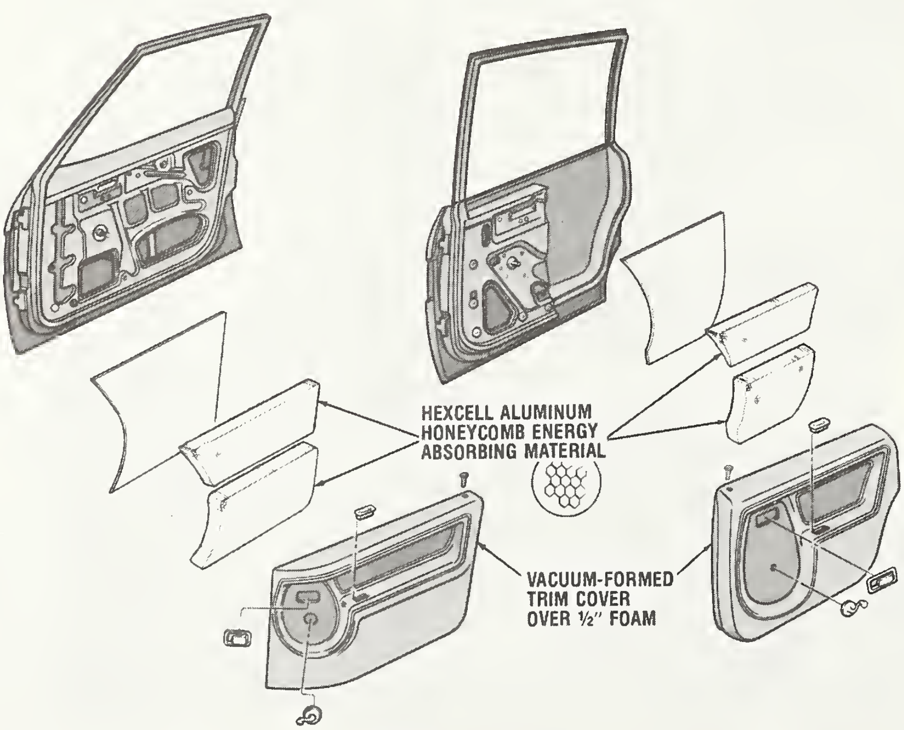

Figure 14. Energy Absorbing Door Trim

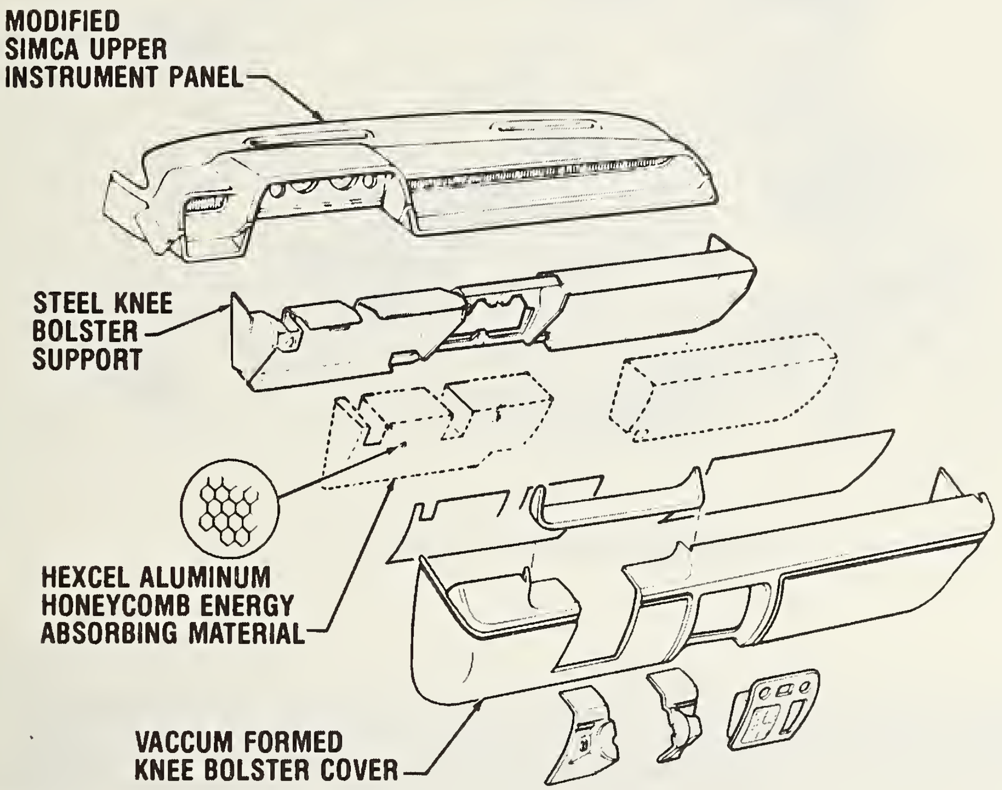

Figure 15. Instrument Panel Construction

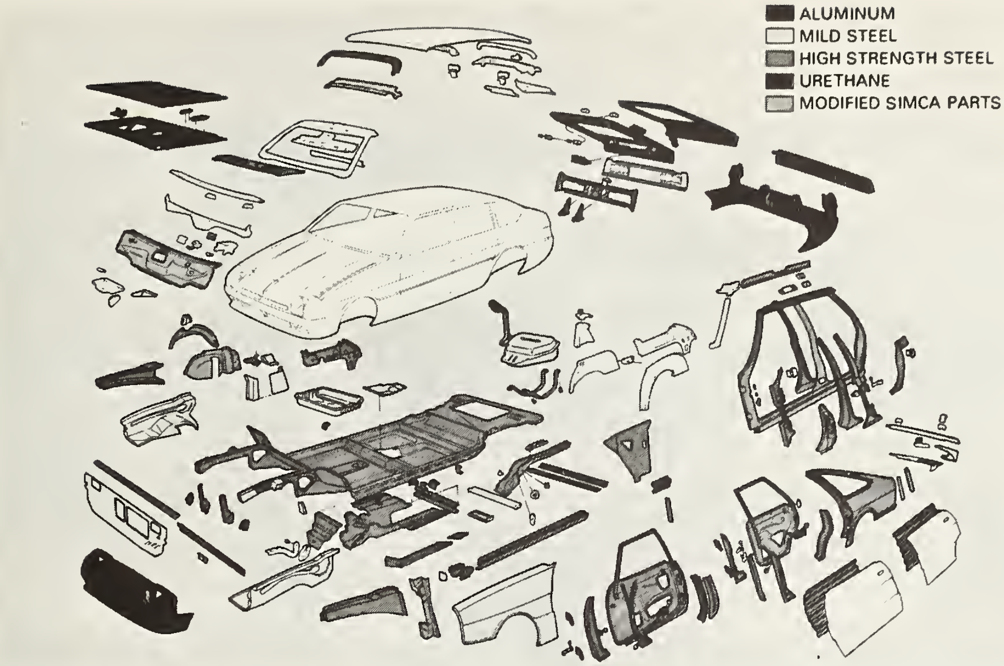

Figure 16. RSV Materials Utilization

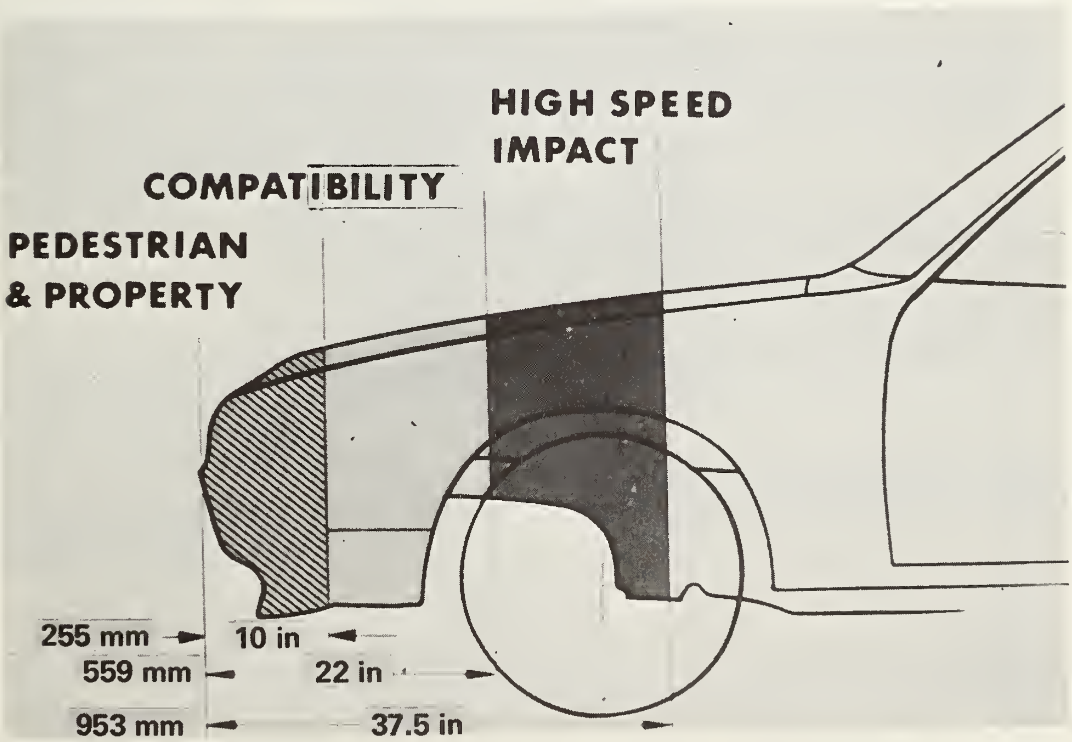

Figure 17. Front Structural Concept

Table 1

EVALUATION OF BASE VEHICLE STRUCTURAL MODIFICATIONS INCORPORATED IN THE RSV

OESIREO PERFORMANCE OBJECTIVE	DESIGN MODIFICATIONS TO BASE VEHICLE	OEMONSTRATEO PERFORMANCE WITH MODIFIEO STRUCTURE
FRONT IMPACT PROTECTION		
• Provide pedestrian impact protection end simultaneously minimize the axtant of exterior damaga to the RSV front and and other conventional vehicles in low-speed, fixed-object/vahicle collisions.	Conventionel front bumper raplaced by soft urathane plastic, energy-absorbing bumper. Material properties and shape selected on the basis of pedestrian contact pressuras/ post-impact Kinamatics and vehicla damageability consideretions. Aluminum hood substituted for steel hood to halp mitigate severity of struck pedestrian injuries.	No damage to extarior sheet metal or bumper shell in flat barriar impacts up to 8.1 mph (Test 1). Only visually epparant damage in e series of front-to-rear impacts with another RSV (Test 2M) was ona minor crack in bumper fascie at 11.4 mph. Low-speed 90 degree side impacts into a Plymouth Fury at spaeds up to 6.1 mph (Test 11A) produced no demage to the RSV, and only minor struck car door skin wrinkling (max. dant approx. 3/16 inch deap). Front end design demonstrated potential for reducing pedestrien injury (both edults end children) at impact speeds up to 20 mph).
• Transmit frontal impact loads into vahicle front rails and sheet metal.	Original radiator support replaced by flat yoke panel which also serves es e mounting surface for the front bumper and headlamp assemblies.	Yoke panel structural integrity mainteined and desired force trensfer manifested in a variety of impact configurations.
• Effectiva Kinetic energy management. Oevelop ralatively low frontel cresh force levels to reduce vehicle aggrassivity in frontal impacts with lighter cars es well es in sida and rear impacts in general. Concurrantly, davelop high crush forces to protect RSV occupants in high-speed frontal impacts with equally-weighted or heavier vehicles.	Simca longitudinal front reils were lengthaned and redesigned using HSLA steel to obtein the desired force lavels/collepse characteristics. Stretegically located slots cut into the first 12 inches of the rail provide the low crush forces required for intervehicular collision compatibility; high forca levels developed in eft portion of the rail. Side engine mounts designed to yield consistent with front rail collepse.	RSV axhibited excallant front-to-sida compatibility in a 90 degree side impect with another RSV at 39 mph (Test 6); striking end struck cars susteined max. exterior crush of 14.4 end 7.3 inches, respectivaly. RSV collepsed in an orderly manner and effectively utilized all availeble frontel crush spaca (lass possible edditional firewall crush) in second and third flat berrier impacts.
• Minimize pitch of passanger compartment.	Upper fender beam added to balence impact forces imparted to the A-pillar. HSLA cowl panel assembly edded batween aft end of fender beem and sill to stabilize beam in vertical banding.	Maximum 4 degrea pitch measured via high-speed film enalysis of flet barrier Tests 9 and 10.
• Limit firawall intrusion into the passenger compartment.	Reinforced A-pillar reacts impact forces transmitted by upper fender beam and directs these forces into the heavily-reinforced sill. HSLA staal substituted for mild steel in front floorpan eraa; joint betwaen firewell end floor pan toeboard strangthened with HSLA strap. Tunnel aree reinforcement installed forwerd of tha firewall to help resist engine/steering rack panetration. Additional rainforcement incorporeted between the aft portion of the front rail end the sill to help resist shear failure of tha floorpan and reil from the sill. Capped sill extension (tire blocker) edded to facilitate direct load trensfer from tira/wheel system to sill.	Structurel integrity of passangar compartment maintained end reletively minor firewall intrusion (4-6 inches mex.) sustained in two 43 + mph flet barrier impacts. Floor pan buckling confined primerily to tha toaboard end tunnel area eft of the front seat riser.
• Prevent windshiald zona intrusion.	Secondary hood latches, located on the fender side shields, installed to help arrest rearwerd motion of the hood.	Windshield cracked but remeined intact during the most severa impect test exposure (barrier Tests 9 and 10). Cracking stemmed from steering wheel rim/instrument panel top contact with innar glass surfaca. Minor intrusion in cowl erea under windshield.
• Facilitata post-crash occupant egress.	See enhenced aperature panel and B-pillar integrity under SIOE IMPACT PROTECTION heading.	One or more doors either manually operable or easily opened with conventional hand tools (e.g., crowbar) following high-speed frontal barrier, perpendicular and oblique front-to-side, and moving berrier rear impact tests.

Table 1

EVALUATION OF BASE VEHICLE STRUCTURAL MODIFICATIONS INCORPORATED IN THE RSV (Cont.)

DESIRED PERFORMANCE OBJECTIVE	DESIGN MODIFICATIONS TO BASE VEHICLE	DEMONSTRATED PERFORMANCE WITH MODIFIED STRUCTURE
SIDE IMPACT PROTECTION		
• Enhanced aperture panel/B-pillar integrity and controlled sidewall collapse.	Single-stamped, continuous aperture panel utilized to reduce the number of required weld joints. B-pillar attachment to sill and roof rail improved. B and C-pillars reinforced with HSLA steel; B-pillar substantially larger in cross section than base vehicle counterpart to facilitate early sidewall loading.	Integrity of sidewall structure maintained in 39 mph perpendicular and 32 mph oblique side impacts by an RSV (Test 6) and a Plymouth Fury (Test 8M), respectively. Max. exterior deformation following the above tests was limited to 7.3 and 9.2 inches (front door region) respectively, with corresponding interior intrusions of only 4.5 and 5.3 inches.
• Impact load transfer/distribution.	Full height HSLA door beams and associated and support structure added to direct impact forces to the aperture panel/B-pillar. HSLA rollbar installed between upper ends of B-pillars to help minimize excessive roof crush and transfer loading to the side opposite impact. Transverse HSLA reinforcement added to floor pan in seat riser area to provide a similar, lower across-the-car load path.	Passenger compartment acceleration-time histories obtained from both impact and non-impact side floor pan-mounted sensors exhibit early onset and comparable magnitudes in Test 6. Deformed RSV sidewall experienced fairly uniform crush, e.g., 7.3 and 6.2 inches of max. exterior deformation near the center of the front and rear doors, respectively.
• Door retention.	Door inward motion restrained by added door interlocks: dual pin-type interlocks installed on door latch faces; L-shaped bracket installed on bottom faces engages a slot in the sill. Base vehicle door hinges strengthened.	Adequate door retention maintained under severe concentrated loading condition imparted to front door during 32 mph oblique side impact by a Plymouth Fury (Test 8M). Similar satisfactory performance demonstrated in 39 mph perpendicular side impact (Test 6).
• Occupant survivability.	See side modifications above. Also, aluminum honeycomb inserts added to space between exterior door skin and interior trim panel to help cushion occupant torso against intruding sidewall structure.	All applicable FMVSS 208 occupant injury criteria satisfied for struck RSV's in Tests 6 and 8M.
REAR IMPACT PROTECTION		
• Reduce extent of rear end exterior damage resulting from low-speed impacts by another vehicle or fixed-object collisions.	Original fiberglass rear bumper replaced by redesigned bumper featuring soft urethane plastic, energy-absorbing inserts. Base vehicle rear crossmember redesigned to increase bending stiffness capacity and help promote impact load transfer into strengthened rear rails/luggage well floor in order to prevent local bumper/rear liftgate panel collapse.	Rear end of struck RSV sustained only minor permanent set (1/8 inch) in lower liftgate panel when struck by the front end of another RSV at speeds up to 11.4 mph (Test 2M). Resulting deformation barely noticeable without comparison of pre- and post-test measurements.
• Limit rear passenger compartment intrusion and provide improved fuel tank protection.	Rear longitudinal rail reinforced to accept loads directed into it by strengthened rear crossmember. Fuel tank moved ahead. Spare tire replaced by luggage well.	A 40 mph colinear rear impact of the RSV by a rigid SAE contoured surface moving barrier (Test 12) resulted in an acceptable 5 inches of passenger compartment intrusion and no damage to the fuel tank. Moderate compartment acceleration environment (24 g's max.) resulted in generally favorable dummy responses.
• Provide additional rear impact protection for fuel tank.	Fuel filler tube rerouted to prevent tube rupture and/or pullout from the fuel tank during rear structure collapse. Quarter panel filler tube attachment redesigned: breakaway plastic retaining collar added to insure tube separation during quarter panel buckling.	Fuel filler pipe integrity maintained in Test 12. Breakaway pipe support demonstrated satisfactory performance.
• Occupant survivability.	See rear modifications above.	With the exception of one femur loading, occupant injury exposure levels for all three dummy occupants were well below, acceptable FMVSS 208 values.

levels, limits the aggressivity. The highest crush forces are developed in the third zone, to protect RSV occupants in high speed impacts. Such a scheme does not provide the highest crush efficiency in frontal impacts; in fact, it leads to somewhat higher peak accelerations on the vehicle, since only low crush forces are experienced during the initial portions of structural deformation in higher speed impacts. However, it was felt that this drawback was outweighed by the improvements effected by providing pedestrian protection and limited aggressivity.

A very careful tuning of the design was required to satisfactorily attain the desired combination of all these capabilities. Tradeoffs were necessary between vehicle aggressiveness and crashworthiness and between intrusion and structural collapse. Reduction of body pitching on impact had to be effected consistent with energy absorbing crush. However, as is the case in any tuned system, variations in any single element seem to have a disproportionate effect since they de-tune the whole system. Consequently, in order to insure the proper operation of the individual elements so that the expected superior performance of the balanced system can be realized, greater effort (and cost) will have to be expended on inspection and quality control during vehicle fabrication than is normally utilized for cars manufactured to current standards.

Major front structural elements exclusive to the RSV include the upper fender beams, front longitudinals designed to collapse in a prescribed manner, strengthened cowl sides, and the central tunnel and floor pan reinforcements which limit engine intrusion into the passenger compartment in high speed frontal impacts (Figure 18). The side structure also serves to provide a load path for some of the frontal crash forces as well as to limit side impact intrusion. Modifications to augment front impact protection are summarized in Table 1.

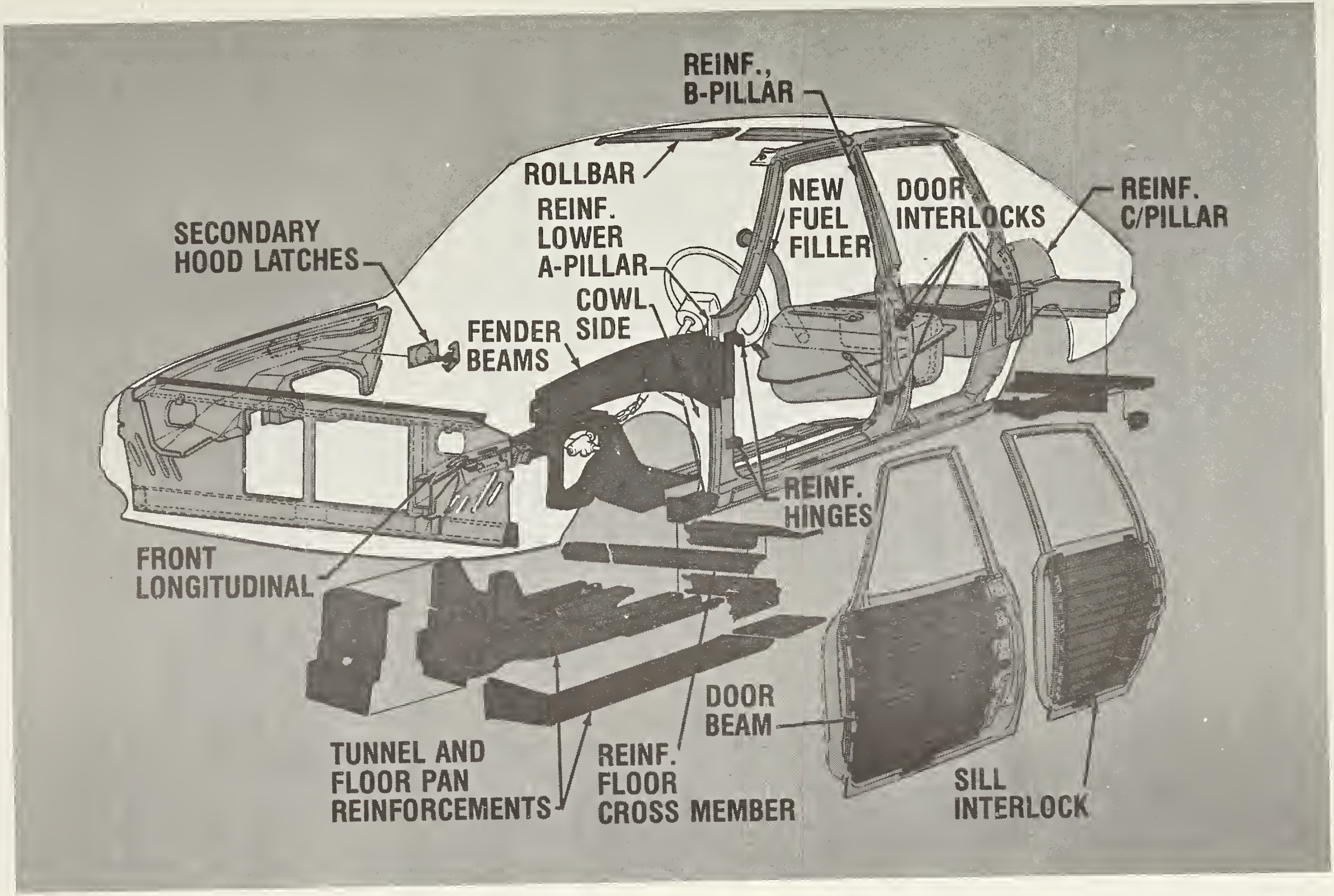

Figure 18 PHASE III STRUCTURE

3.2.2 Side

Structural modifications to the RSV sides (Figure 18) include stronger door hinges, interlocks into pillars and sills, as well as large door beams to carry loads across doors. This HSLA beam, extending from glass to sill and from latches to hinges, is bonded to the door outer skin for increased efficiency and reduced weight. The front door glass was shortened at its forward end to clear the beam and rear door window glass opening distance was reduced for the same reason. Reinforcements were added to the A, B and C pillars. Utilization of a single stamped "aperture panel" for the area surrounding both front and rear doors reduces the number of weld joints and improves side strength. To prevent the side of the car from collapsing inward during impact, a roof reinforcement (rollbar which also provides improved roof crush strength) was added across the top between the B pillars and a transverse reinforcement was similarly added to the floor under the front seats.

These elements indicated in Table 1 serve to limit intrusion during side impact. Minor deformation of the door beam occurs after initial contact by a striking car. Through the door interlocks, the beams then engage the rigid base formed by the transverse members and strengthened door openings. Thus, the beams act more efficiently as tension members rather than as simple bending elements and combine with the rest of the structure to provide exceptional side impact performance even when hit by much larger cars.

3.2.3 Rear

The rear structure of the Simca required minimal modification (Figure 18 and Table 1). The fuel-tank filler neck was rerouted to obtain better protection in crashes. Location of the Simca fuel tank between the rear wheels, well forward of the rear end, was retained although its capacity was slightly reduced to provide added luggage volume. Rear longitudinals and rear crossmembers were reinforced primarily for low speed damage reduction and the rear end of the hatch lid and rear fenders were altered to permit attachment of the soft bumper and spoiler.

3.3 Body Components

Although most body hardware components were retained intact from the Simca 1308, a number were somewhat modified to better suit specific requirements of the RSV. These parts include the instrument cluster, seats (reinforced and recliner mechanism removed), window mechanisms, most glass, door and hatch latches, and various other small components. Some special elements were used, the most significant being the soft foam filled bumpers, new front and rear lighting, special windshield, and the hood latch systems.

The soft, urethane-plastic foam-filled bumpers are unique, as shown in Figure 19.[8] They protect the RSV from damage in barrier impacts up to 13 kph (8 mph), 8 kph (5 mph) rear collisions, and 21 kph (13 mph) front-to-rear crashes between RSVs.[11,15] More importantly, with this bumper, a capability for the reduction of pedestrian injuries has been demonstrated at speeds up to 32 kph (20 mph) for both adults and children.[9]

Preliminary computer studies were used to establish the bumper shape and its force-deflection properties. Both factors were found to be significant in limiting injuries. Force properties primarily limit bone fractures and, combined with overall shape, can affect pedestrian kinematics after contact and reduce contact forces with other car elements and with the ground. The aluminum hood, in addition to saving weight, enhances the bumper properties by being "softer" than a steel hood. (There is some disadvantage, however, in that the hood can be more readily damaged in non-impact situations.) Fortunately, the rounded bumper shape has proven to be compatible with aerodynamic needs, although it does not fully comply with present U.S. bumper standards and was not designed to do so. In fact, current U.S. standards pertain to protecting the vehicle on which the bumper is installed rather than pedestrians. The fixed headlamp covers, installed primarily to improve aerodynamics, also aid the pedestrian by providing surface continuity.

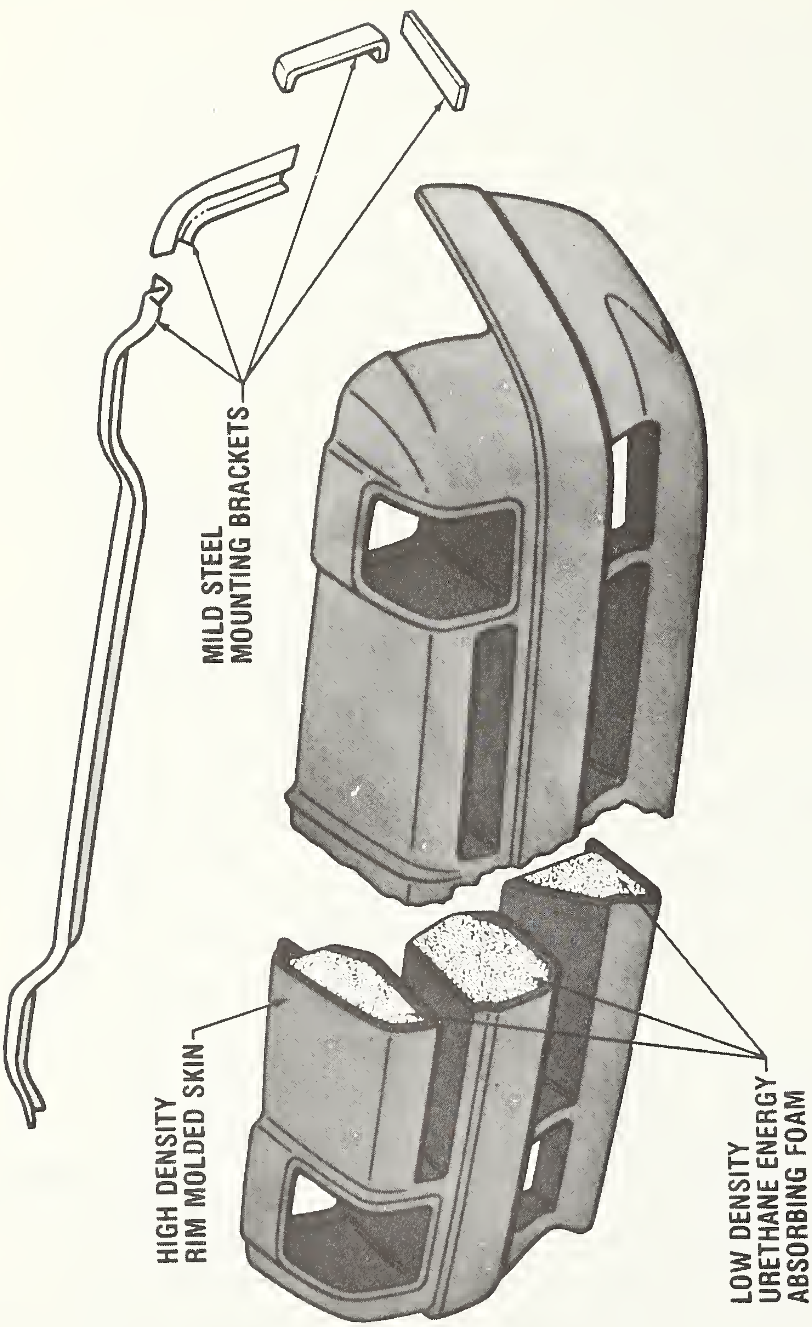

Figure 19. Pedestrian Protecting Bumper

RSV headlamps (Figure 20) have only one beam and use a plastic lens to attain precise aiming for improved lighting with reduced glare while effecting a weight savings (Figures 21 and 22). While not fully developed, this system could have safety advantages by providing better lighting, and eliminating improper beam usage. A suspension activated hydraulic headlamp aiming system is available to automatically compensate for vehicle loading and dynamic effects. High-level rear lamps are located on the rear roof pillars (Figure 23). They combine running, side-marker, stop, and turn functions in a highly visible location.

The RSV windshield is similar to current U.S. three-layer units but is somewhat thinner and has a fourth plastic inner layer. This layer, to a large extent, eliminates lacerative injuries to unrestrained occupants.

A special hood latch system with the secondary catches remotely located along the hood sides is used (Figure 24). A conventional, interior-actuated primary latch is located at the front of the hood. Secondary catches provide improved crush efficiency for the lightweight aluminum hood by increasing the number of buckles formed in it during frontal impacts. The secondary latches prevent the hood from entering the windshield lower zone and stabilize the fenders laterally in angled or offset collisions.

3.4 Restraints

Development of the RSV occupant restraints began early in Phase II using the Calspan developed crash victim simulation computer program (CVS III)[5] with input decelerations provided by complete car crush simulations from Chrysler. Preliminary results of these studies indicated that an advanced belt system[19] could provide a survivable impact speed about 8 kph (5 mph) greater than an air bag system. The parametric studies were confirmed by tests on a HYGE impact sled. While the sled results were not exactly equivalent to the computer predictions, based on FMVSS 208 tolerance levels front seat occupants could be assured survivability with the projected RSV structural

Figure 20 RSV PLASTIC HEADLAMP

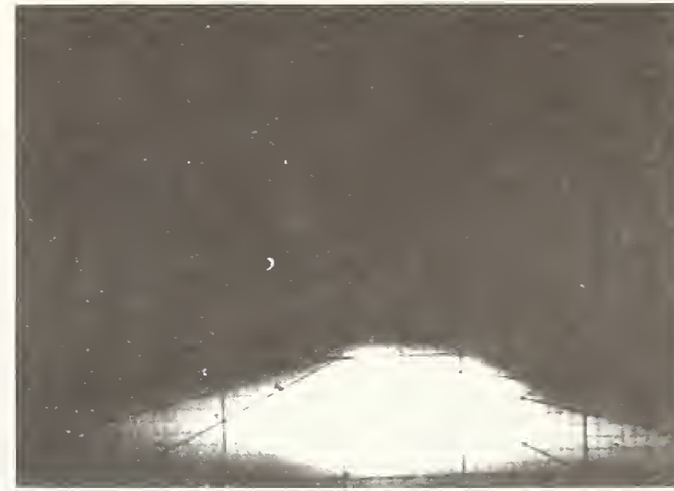

Figure 21 STANDARD TUNGSTEN SEALED BEAM LOW BEAM

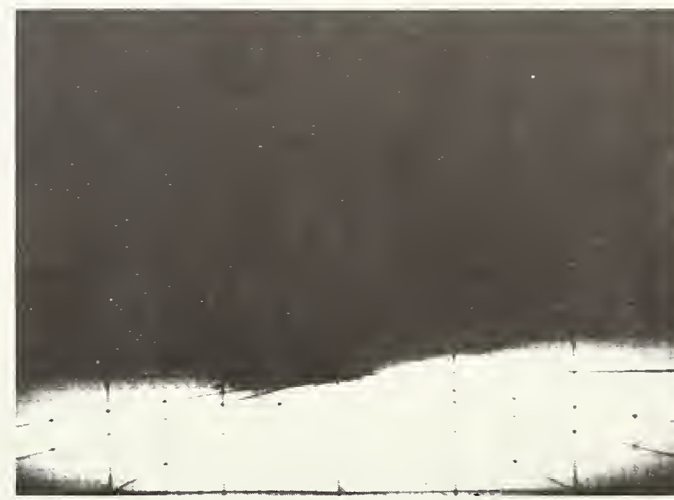

Figure 22 RSV HEADLIGHT BEAM

Figure 23. RSV High Level Rear Lamp

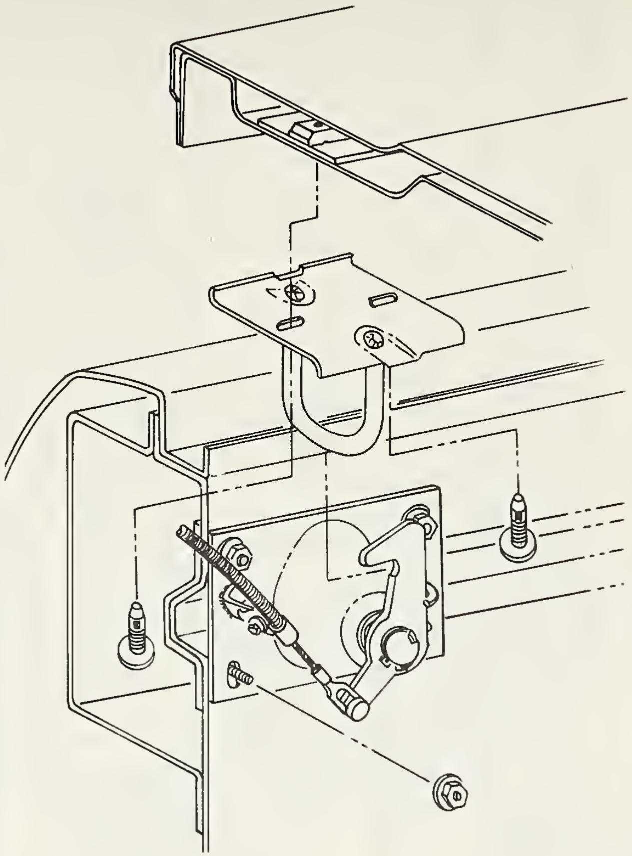

Figure 24. Secondary Hood Latch — Phase III

response. The Phase II cars incorporated such a belt to take advantage of the indicated greater impact speed potential.

Subsequently, for use in Phase III, NHTSA awarded additional contracts for development of air bag type restraints for both the driver and front passenger. The passenger system was not developed sufficiently to be included in the vehicle, but the driver air bag system[4] was selected for the final RSVs to demonstrate an available alternate automatic system.

The driver's restraint (Figure 25) incorporates a steering wheel mounted air bag with a sodium azide inflator, porous nylon bag, dual radiator yoke mounted impact sensors (1973 GM type) and a dash mounted diagnostic box with integral back-up crash sensor. For the front passenger, the restraint system (Figure 26) is a motorized, automatic inflatable torso belt with the inflator mounted between the seats (a single inflator could serve two belts for both front occupants), force limited webbing, and an inertia retractor. Both systems offer optional active lap belts made of force limiting webbing to supplement the previously described "knee blocker" instrument panel and to minimize chances of ejection during impact. In the interest of simplicity, the belt system uses the same sensors as the air bag. When deployed, the inflatable element eliminates belt slack (required for comfort), distributes forces over the torso and, since it extends under the chin, reduces passenger head motions. Force limiting webbing limits the occupant accelerations to accepted tolerance values. When the ignition is turned off, a motor drives a flexible cable pulling the movable D ring forward to the upper right corner of the windshield, allowing ready entry and egress by the front seat passenger.

The air bag system has advantages in that it is completely passive, unobtrusive, and provides effective distribution of impact forces on occupants. A strong point for the improved belt is that it is anchored farther back in the vehicle structure and thus may not be as susceptible to degradation of performance should serious intrusions occur. Also, since as a normal belt it provides satisfactory restraint up to 30 mph, belt system inflation could be

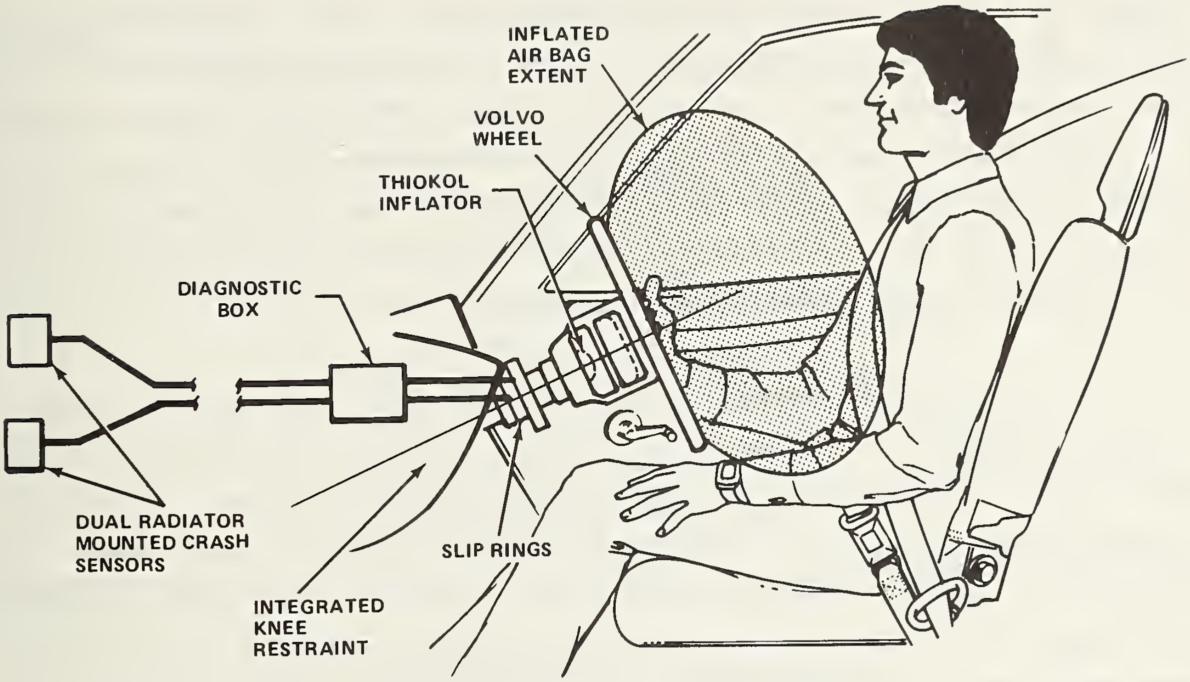

Figure 25 DRIVER RSV AIR BAG SYSTEM

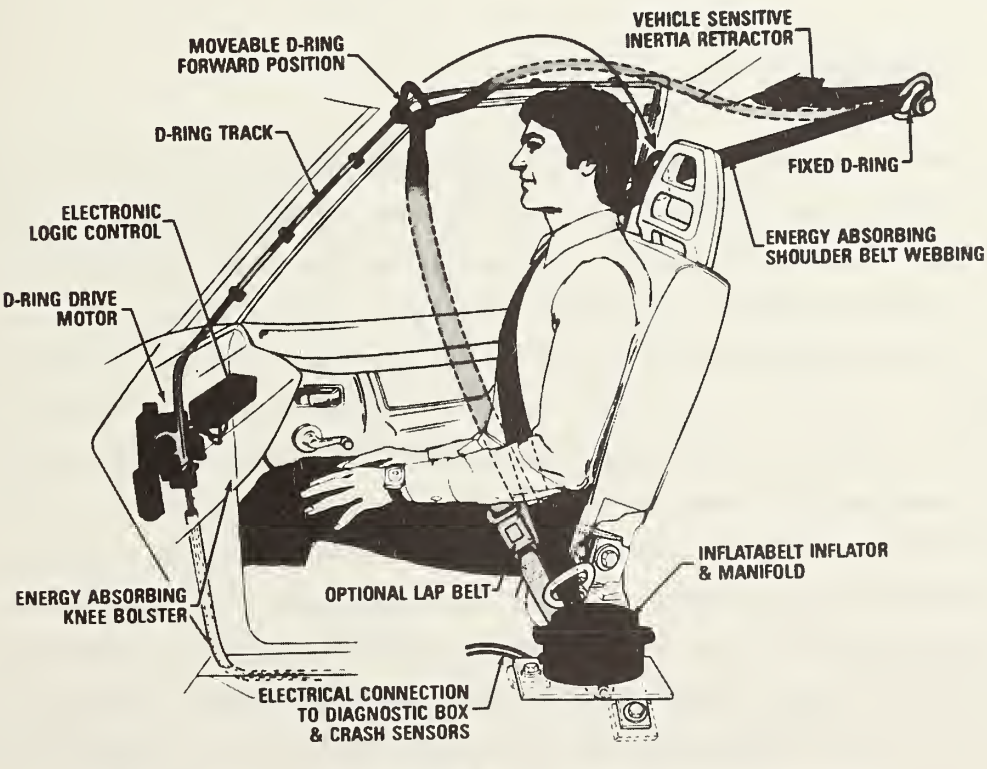

Figure 26 RSV INFLATABLE SHOULDER BELT – PHASE III

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deferred to a higher impact speed than the air bag. This could result in repair cost savings since restoration of the system after crashes would be needed in fewer instances. In addition, a belt supplies some lateral support for accidents other than frontal impacts. On the other hand, the automatic inflatable belt has two major shortcomings: it is nearly as expensive as the air bag and it is far more likely to result in owner/occupant objections to its discomfort, inconvenience, and appearance.

Force limiting webbing is used in the active belts for the three rear seat positions. Three-point restraints with inertia retractors are provided for the outboard positions and a lap belt for the center. While these devices provide a lower level of impact performance than the front seat restraints, they were considered satisfactory and consistent with maintaining reasonable vehicle costs in view of markedly lower use of the rear seats. Sheet metal panels on the backs of the front seats serve to absorb rear passenger knee contact forces and prevent consequent injuries to front passengers.

3.5 Aerodynamics

An aerodynamics study was undertaken during Phase III[26] involving a complete, full-scale car test performed at the National Research Center wind tunnel in Ottawa, Canada. Many aerodynamic features were investigated on a Phase III prototype and the measured effects on drag are tabulated in Figure 27. Some tradeoffs were made to achieve this level of performance. For example, the initial rear vision goal was similar to the current proposed standard for indirect visibility. An analysis of that goal indicated a need for very large outside rear view mirrors on both sides of the car. The right side mirror had the further disadvantage of having to be placed atop the right fender forward of the windshield. The size and location of these mirrors would increase drag as well as present a potential hazard to pedestrians. It was decided that these elements outweighed the advantages of improved indirect vision. The fixed headlamp covers described earlier in the bumper section

CONFIGURATION	DESCRIPTION	C_D	ΔC_D%
1	BASE CAR	.474	0
2	(1) w/45 MM REAR SPOILER	.438	7.8
3	(2) w/HEADLAMP COVERS	.421	11.4
4	(3) w/FLUSH WHEELCOVER	.415	12.6
5	(4) w/CONVEX WHEEL FAIRING	.413	13.1
6	(5) w/FAIRED DRIP MOLDING & REAR QUARTER WINDOW	.412	13.3
7	(6) w/REAR WHEEL ARCH SKIRT	.411	13.5
8	(7) w/FRONT VERTICAL AIR DAM	.408	14.1
9	(8) w/CENTER GRILL INLETS ONLY AND TWO AERODYNAMIC MIRRORS	.405	15.4

Figure 27 RSV WIND TUNNEL TEST RESULTS

were similarly found to provide major aerodynamic improvements as well as a potential advantage to pedestrians. Therefore, they are used in the RSV despite their non-concurrances with current U.S. regulations.

3.6 Chassis

The RSV goals include a 7.84 litres/100 km (30 mpg) combined city/highway EPA cycle fuel economy and emissions of 0.41 HC, 3.4 CO, and 2.0 NOx gpm. The high cost of developing an entirely new type of emissions systems would have diluted the primary objective of safety. Instead, a current production engine was selected to replace the Simca unit. Installation of a 1.7 liter Omni/Horizon engine in the RSV required redesign of the engine accessory drives and relocation of other engine compartment components as well as increase in the front overhang. The very good aerodynamics of the RSV result in a fuel economy rating exceeding the 8.55 litres/100 km (27.5 mpg) combined city/highway average required of all U.S. cars by 1985. Emissions levels meet 1979 California requirements. The remainder of the RSV driveline is also Omni/Horizon with both manual and automatic transmissions available.

The other chassis items have been changed from their Simca or Omni/Horizon counterparts only as required to meet the specific installation or weight requirements of the RSV. The Simca brakes have been altered to provide a diagonal split (Figure 28) to give improved braking when the system is partially failed. Further development of an adaptive (four wheel, electronically modulated) braking system is currently underway for installation on the RSV.

A break-away lower steering column member (Figure 29) is used to reduce steering wheel rearward motion during high speed frontal impacts by separating the steering rack and pinion gear from the upper column after about one inch of crush takes place aft of the front wheels.

The tire system utilizes a flatproof tire (Figure 30). When the pressure is removed, the thicker sidewalls support the car weight and car handling response is not severely affected. A low tire pressure warning system

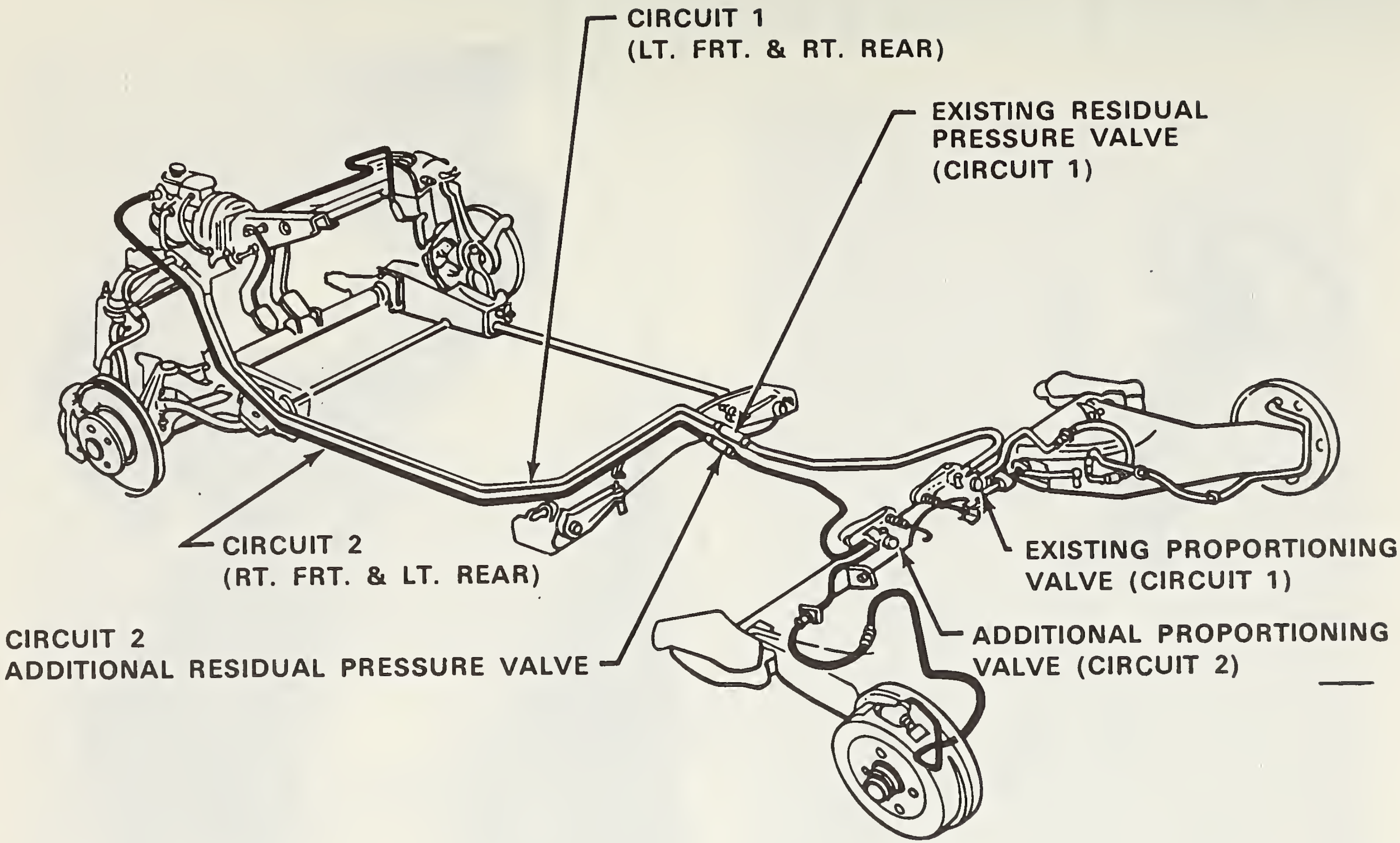

Figure 28 BRAKE LINE ROUTING FOR RSV WITH DIAGONAL SPLIT SYSTEM

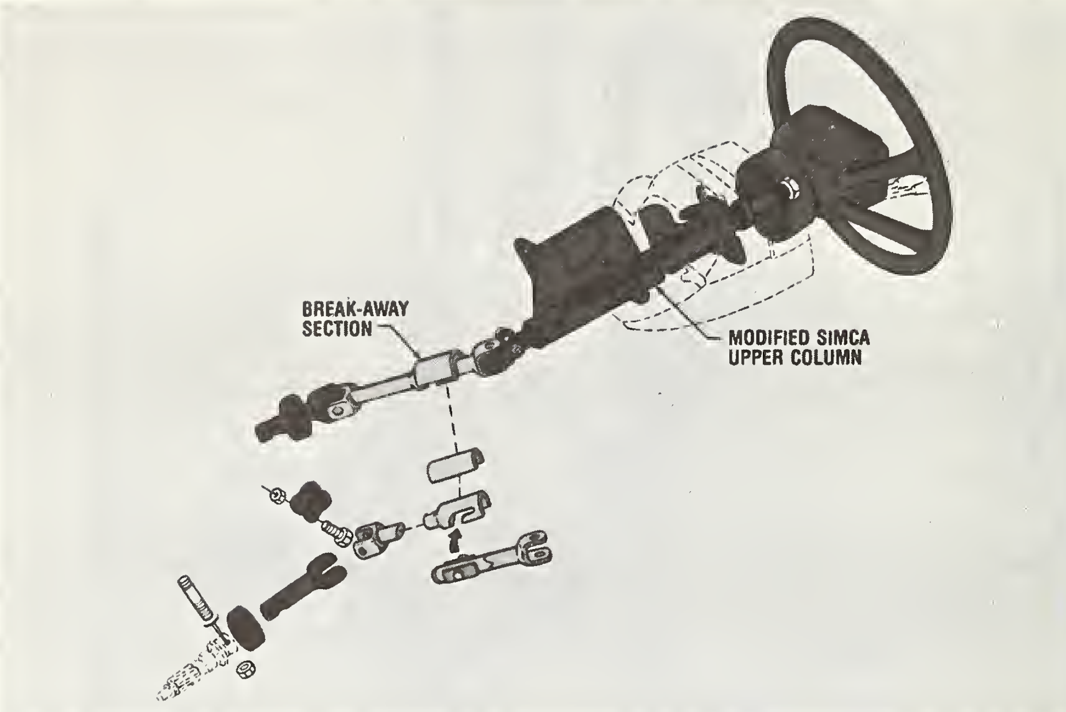

Figure 29. Breakaway Steering Shaft

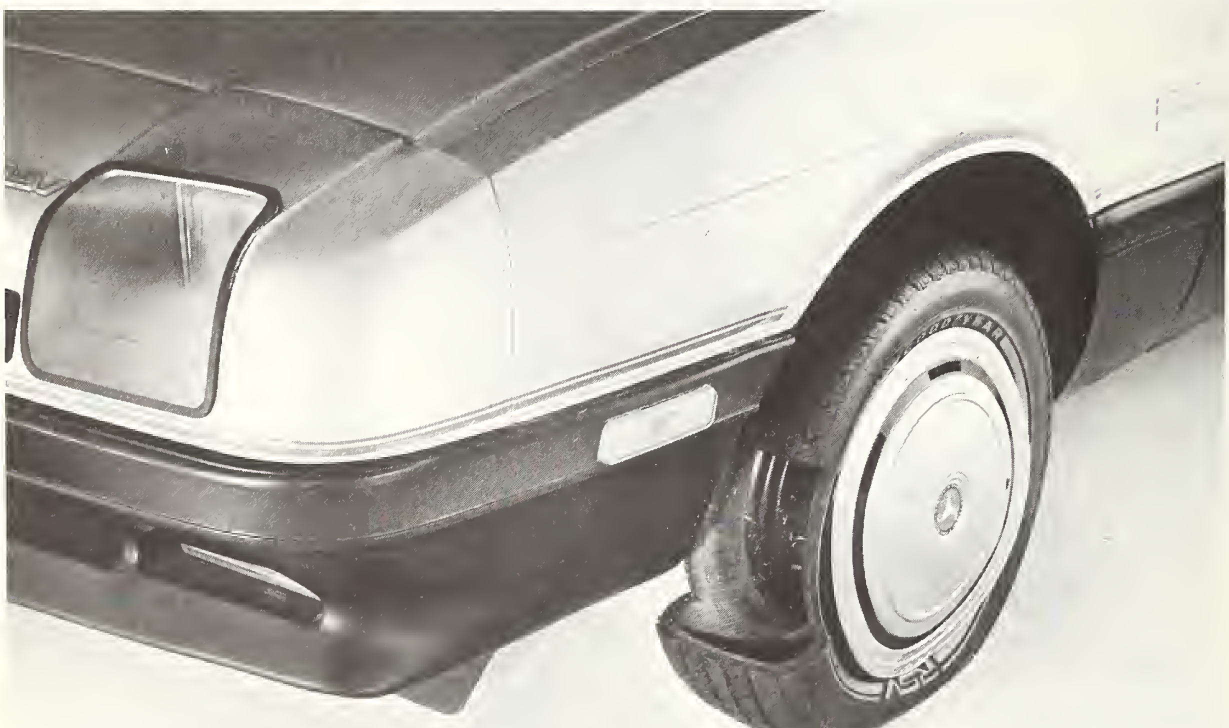

Figure 30. Flatproof Tire

is included to provide an instrument panel indication when any of the four tires has less than 115 kilopascals (17 psi). The car can be driven up to 65 km (40 miles) at speeds up to 65 kph (40 mph) to a service station without damaging the tire, providing added safety by eliminating the hazards of roadside tire changing. There is also a small weight savings (albeit at added cost) afforded by replacing five tires and the jack with four flatproof tires even though they weigh more individually than the standard ones. A substantial increase in luggage volume is also achieved.

3.7 Weight

Since fuel economy is closely associated with vehicle weight, particular attention was paid to changes in weight resulting from design modifications during the development of the Calspan/Chrysler RSV.[26] The success of that activity is attested by the fact that the measured curb weight of 1213 kg (2675 lbs.) is only 3 kg (7 lbs.) above that shown on the September 1978 weight report, several months prior to completion of the first Phase IV RSV (Figure 31). The curb weight represents an increase of 161 kg (355 lbs.) over the base French Simca, but since it is estimated that about 60 kg (132 lbs.) would have to be added primarily for emissions, bumpers, and door crush resistance to meet current U.S. regulations, the weight attributable to the RSV features is about 101 kg (223 lbs.).

3.8 Costs

Obviously, all of the added RSV safety features cannot be obtained without some penalties. As noted, the curb weight of the Calspan/Chrysler RSV is estimated to be 101 kg (223 lbs.) greater than a "federalized" Simca. That added weight results in increased operating costs due to reduced fuel economy. In addition, the added complexity of the vehicle subsystems and structure might result in additional maintenance costs. Increased part and labor content in the more complex RSV will probably result in higher manufacturing costs and consequently increased consumer cost. On the other hand,

		PHASE III		
		KG		LBS
BASE CAR (SIMCA C-6)	(1050.794)		(2317.00)	
ADJUSTED BASE CAR		1029.411		2264.69
FLIGHT STRUCTURE		64.784		142.85
SIDE STRUCTURE		73.22		161.45
SIDE EXCLUSIVELY	(20.843)		(45.96)	
FRONT/SIDE	(48.803)		(107.61)	
SIDE ROLLOVER	(3.574)		(7.88)	
REAR STRUCTURE		3.598		7.94
OCCUPANT PROTECTION		39.610		87.34
ENVIRONMENTAL PROTECTION		9.614		21.20
STEERING & SUSPENSION		–4.739		–10.45
PRODUCIBILITY & SHIPPING				
TOTAL CAR		1210.755		2669.62

Figure 31 RSV CRASHWORTHINESS WEIGHT STATUS

however, the benefits of reduced damageability and improved safety might more than offset those increases.

A detailed consumer price analysis has been carried out by Chrysler personnel, assuming an annual production of 300,000 units with a normal amortization.[26] Since the Simca is neither manufactured nor sold in the U.S., and the French manufacturing facilities, procedures, and labor rates are not specific to the U.S., an actual total consumer cost for a federalized RSV is not available. However, cost differentials between the RSV and a car of the same size and general features meeting current U.S. standards (federalized Simca) were derived as summarized in Figure 32. The total differential in retail price, including research and development, facilities, tooling, and other expenses associated with bringing such a car into production, is shown to be $1795 in 1979 dollars. Although a major number of the items appearing in the estimate are the type Chrysler presently fabricates, a disproportionately large portion of the estimated cost is associated with a limited number of components that are not now in production and would have to be purchased. Chrysler had only vendor's estimates to use in assembling the costs for the passive restraint systems, anti-skid brakes, and flatproof tires which comprise the high technology category of the RSV features as shown in Figure 33. The vendor-supplied costs for these three elements are dependent on the supplier's estimate of the market that does not admit detailed analysis; they dominate the cost differential, representing 60 percent of the total incremental cost. Concurrently, the basic vehicle features which are closely related to parts currently being manufactured, account for only 29 percent of the total, with the optional or discretionary features constituting the remaining 11 percent of the cost difference.

Although we believe this to be the best estimate that can currently be obtained, since it is based on the most reliable information available, it is true that the closer an item is to being in production at the desired rate, the more nearly the actual cost can be assessed. Chrysler has expressed a view that while these costs are realistic, they may be somewhat optimistic;

PART GROUP	ADDITIONAL CONSUMER COST
BODY-IN-WHITE	$ 203
FRONT SHEET METAL	23
GLASS	28
PAINT, SEALERS & DEADENERS	-0-
BUMPERS	107
GRILLE & LIGHTS	31
EXTERIOR ORNAMENTATION	54
INSTRUMENT PANEL	-0-
STEERING WHEEL	-0-
INTERIOR TRIM	138
FRONT RESTRAINTS & KNEE BLOCKER	642
REAR RESTRAINTS	34
CHASSIS & ELECTRICAL	22
FLATPROOF TIRES & SENSOR SYS.	102
ADAPTIVE BRAKE SYSTEM	325
HEADLAMP LEVELING SYSTEM	45
MISCELLANEOUS	41
TOTAL	$1795

Figure 32 CONSUMER COST SUMMARY

	CONSUMER COST	
HIGH TECHNOLOGY FEATURES		
FRONT PASSENGER RESTRAINTS, INCL. KNEE BLOCKER	$ 642	
FLATPROOF TIRES & LOW PRESSURE WARNING	102	
ADAPTIVE BRAKING SYSTEM	325	
	$1069	(60%)
DISCRETIONARY FEATURES		
4-PLY WINDSHIELD	$ 28	
REAR SPOILER	30	
HALOGEN HEAD LAMPS & COVERS	14	
HEADLAMP ADJUSTING SYSTEM	45	
HIGH LEVEL REAR LAMPS	21	
RUB STRIP MOLDING	24	
SOFT WHEEL COVERS	30	
ALUMINUM HOOD & HATCH LID	16	
	$ 208	(11%)
BASIC FEATURES		
BODY STRUCTURE & HARDWARE	$ 210	
SOFT FRONT & REAR BUMPERS	77	
INTERIOR TRIM & PADDING	138	
3-POINT REAR BELTS	34	
MISCELLANEOUS OTHER ITEMS	59	
	$ 518	(29%)
TOTAL	$1795	(100%)

Figure 33 RSV CONSUMER COST FEATURE CATEGORIZATION

they should fall within a normal 10 to 20 percent band. However, since 60 percent of the cost represents three major elements not yet scheduled for production, careful monitoring of variations in these costs will be necessary because of the leverage of these items on the total cost differential.

4.0 TESTING

A number of tests were conducted during Phases II and III to assess the performance capabilities of components and systems being designed and built for the RSV. Phase III tests are summarized here; more detail is given in Volume II and in the references. Static crush tests[10] were used to predict structural performance in dynamic impacts; sled tests[4,19] with a postulated acceleration pulse, to indicate dummy occupant performance in car crashes. A number of barrier and car-to-car crash tests[11-18,21] were run to evaluate occupant survivability and handling tests[22,23] provided information on vehicle driveability and response. In addition, aerodynamics, fuel economy, emissions, flatproof tire performance, braking and acceleration were investigated experimentally.[26]

The different integrated systems validation tests conducted in Phase III are summarized in Table 2 by category. The structure of the RSV was designed with the goal of having the front seat occupants comply with FMVSS 208 injury criteria for barrier impact crashes in the 65-80 kph (40-50 mph) range.[10] As indicated in the table and test reports,[18,21] the two frontal barrier crashes at 69 and 71 kph (43 and 44 mph) did not provide valid tests of the restraint systems because of malfunctions in ancillary components. However, in a subsequent barrier test of one of the Phase IV RSVs in Phoenix, Arizona, the driver protected by an air bag mounted in a modified steering wheel passed FMVSS 208 requirements at 66 kph (41 mph) except for one femur that was 50 lbs. high. The rear crash of a moving barrier into an RSV at 65 kph (40 mph)[20] demonstrated satisfactory occupant performance. When struck from the side at 62.9 (39.1 mph) in another test,[14] the dummies on the struck side, as well as those in the striking RSV, indicated survival. In another test, a 4200 lb. Plymouth at 51 kph (32 mph) striking the RSV on the side at 60 degrees provided similar results.[16] Results of further experiments with the RSVs tested in Phase IV are included in Section 15 of Volume II to provide more evidence of the performance achieved.

Table 2
RSV PHASE III INTEGRATED SYSTEMS VALIDATION TESTS

TEST CATEGORY	TEST NO.	DATE	TEST DESCRIPTION	IMPACT SPEED (mph/kph)	REMARKS
Low speed damageability	1	1/13/78	Frontal Flat Barrier (low-speed vehicle damageability - 4 impacts)	5.4-8.1/8.7-13	Acceptable at 7.3 mph, minor damages at 8 mph.
	2	3/31/78	Front-to-rear colinear (low-speed vehicle damageability - 2 impacts)	6.2-8.0/10-12.9	Testing terminated because of unacceptable damage to original phase III rear panel/crossmember assembly.
	2M	4/13/78	Front-to-rear colinear (low-speed vehicle damageability - 5 impacts)	6.1-12.9/9.8-20.8	Repeat of Test 2 with modified rear panel/crossmember assembly. Marginal damage to striking car at 11.4 mph.
	4	1/26/78, 1/27/78	Modified FMVSS 215 pendulum impacts (low-speed vehicle damageability - 8 impacts at various locations along front and rear bumper surfaces)	2.9-5.0/4.7-8.0	Tests conducted with original Phase III-design rear panel/crossmember assembly. No damage to front bumper head lamps, sheet metal. Apparent damage to rear prior to modification.
	11	4/6/78 4/7/78	Low-speed RSV impacts into stationary Plymouth Fury • 90° front-to-side (3 impacts) • Front-to-rear colinear (2 impacts) • Front-to-front colinear (3 impacts)	 4.0-8.1/6.4-13 5.2-8.1/8.4-13 9.1-12.8/14.6-20.6	 No damage to RSV front at 8 mph into Plymouth side and rear. Front-to-front damage to RSV at 10.8 mph.
Flat frontal barrier	3	1//19/78	Frontal flat barrier	46.1/74.2	Unsuitable collapse model and pitch by original Phase III front structure. Front seat occupants restrained by two-point torso air belts exceeded allowable maximum.
	9	3/15/78	Frontal flat barrier	44.1/71	Repeat of Test 3 with modified front structure. Front seat occupants restrained by two-point torso air belts. Restraint system component failure prevented air belt inflation. Structure performance and pitch adequate.
	10	6/28/78	Frontal flat barrier	43.3/69.7	Phase III RSV equipped with Phase IV prototype front structure. Driver and right front passenger dummies restrained by RSV-design air bag and air belt systems, respectively. Structure results similar to Test 9, deceleration greater, driver protected by air bag, exceeded injury criteria. Passenger air belt failure allowed excessive HIC number.
Rear moving Barrier	5	1/31/78	Colinear rear impact by moving barrier	39.6/63.7	Fuel tank overflow vent tube rupture and loss of fuel filler cap during impact led to fuel leakage which exceeded FMVSS 301-75 limits.
	12	5/15/78	Colinear rear impact by moving barrier	40.4/65	Repeat of Test 5 with rerouted overflow vent tube, breakaway fuel filler pipe support and modified rear panel/crossmember assembly. No fuel leakage, but one rear femur high.
Front-to-side	6	4/21/78	90° front-to-side	39.1/62.9	Excellent crashworthiness, all occupants survive
Vehicle Compatibility	8	4/26/78	60° front-to-side impact by Plymouth Fury	32.0/51.5	Front door hinge weld failure produced unacceptable loss of side structure integrity.
	8M	5/3/78	60° front-to-side impact by Plymouth Fury	31.7/51	Repeat of Test 8 with strengthened door hinge attachment. Excellent (9") side crush & intrusion (5") control. Occupant injury levels well below maximum.

The steering and handling information taken from References 22 and 23 are indicated in Table 3. In summary, the RSV handling characteristics satisfactorily meet the specifications in all respects. Table 4 indicates that after an initial preburnish test, the braking performance exceeded the spefification.[26] The RSV prototype stopped from 96.5 kph in 46 meters (60 mph in 151 feet) with a maximum pedal force of 68 kg (150 lbs.). In subsequent fade and recovery tests, the pedal force to obtain a deceleration of 3 meters (10 feet) per second per second (0.31 g's) varied from 12 to 14 kg (26 to 31 lbs.), while that required to achieve 4.6 meters (15 feet) per second per second (0.465 g's) varied from 20 to 24 kg (45 to 52 lbs.) Acceleration test data shown in Table 5 similarly exceeded the minimum acceptable levels defined in the specification developed in Phase I of the RSV program.[1] That specification is included as the Appendix to Volume II of this report along with values of the various parameters obtaind by measurement of the final RSV.

In general, in all areas where RSV performance was quantified, test data show minimum goals were met or exceeded. RSV weight, for instance, is below the 1360 kg limit even with a fully optioned car; braking performance levels were easily exceeded; handling goals were met; acceleration performance is acceptable. A few areas, however, did not yield results anticipated. Frontal impact performance met minimum goals, but better capabilities were expected. Structural response was generally good, but decelerations required to achieve the three-zone concept[26] were higher than anticipated.

Table 3
RSV HANDLING PERFORMANCE

CATEGORY	PERFORMANCE			REMARKS
	SPEC-IFICATION	SIMCA 1308	RSV	
STEERING				FOR STEADY STATE LATERAL ACCELERATION OF .4 g
• STEADY STATE YAW RESPONSE GAIN	SHOWN IN FIGURE 31 VOL II			UNDERSTEER GRADIENT ≐ 3 deg/g
• TRANSIENT YAW RESPONSE	SHOWN IN FIGURE 32 VOL II			SPECIFIED AT 25 & 70 mph
• RETURNABILITY	SHOWN IN FIGURE 33 VOL II			SPECIFIED AT 25 & 50 mph
HANDLING				
• LATERAL ACCELERATION	SHOWN IN TABLE 5 VOL II			SPECIFIED IN TERMS OF COMBINATIONS OF ± 20% OF RECOMMENDED TIRE INFLATION PRESSURE
• CONTROL AT BREAKAWAY	PATH RECOVERY WITHIN 4 secs	–	PATH RECOVERED IN 3.5 - 4.5 secs	MANUAL CONTROL, CLOSED-THROTTLE OPERATION TO RECOVER 100 ft RADIUS PATH FROM 110 ft RADIUS AT HIGH LATERAL ACCELERATION
• DIRECTIONAL STABILITY	$<$1 ft	–	NEAR ZERO	SPECIFIED AT LATERAL DEVIATION 2 secs AFTER DISTURBANCE CONTACT
• STEERING SENSITIVITY	$>$5 in-lb	–	$>$5 in-lb	SPECIFIED FOR YAW RATE OF 2 deg/sec AT SPEED OF 30 mph OR GREATER
OVERTURNING IMMUNITY				
• SLALOM	45 mph	–	50 mph	100 ft PYLON SPACING
• BRAKE/STEER	–	–	–	LITTLE AMPLIFICATION OF STEADY STATE ROLL ANGLE

Table 4

RSV BRAKING PERFORMANCE

CATEGORY	PERFORMANCE			REMARKS
	SPECIFICATION	SIMCA 1308	RSV	
SERVICE BRAKE EFFECTIVENESS				
• STOPPING DISTANCE FROM 60 mph	190 ft	153 ft	151 ft	RSV PEDAL FORCE ~100 lbs
• STOPPING DISTANCE FROM 60 mph WITH BOOSTER FAILURE	350 ft	199 ft	192 ft	RSV PEDAL FORCE = 150 lbs
• STOPPING DISTANCE FROM 60 mph WITH PROPORTIONING SYSTEM FAILURE	250 ft	194 ft	157 ft	RSV PEDAL FORCE ~ 75 lbs
• STOPPING DISTANCE FROM 60 mph WITH 1/2 SYSTEM FAILURE	400 ft	300 ft	329 ft	RSV DATA FOR BOTH LIGHT AND MAXIMUM LOAD; PEDAL FORCE $<$150 lbs
• FADE & WATER RECOVERY	FMVSS 105	–	SATISFIES FMVSS 105	RSV FADE: PEDAL FORCE 26 lbs FOR 10 fps^2; RSV RECOVERY 29 lbs FOR 10 fps^2
• BRAKING-IN-TURN; STOPPING DISTANCE FROM 40 mph ON 357 ft RADIUS ARC	90 ft	–	85 ft	
PARKING BRAKE				
• (30% GRADE)	$<$90 lbs	–	$<$86 lbs	FOR BOTH UPHILL AND DOWNHILL ORIENTATIONS

Table 5

RSV NO. 8 ACCELERATION TEST RESULTS

	ACTUAL MEASURED VALUE	"MINIMUM ACCEPTABLE" LEVELS FOR RSV
W.O.T. ACCELERATION THROUGH THE GEARS		
SPEED-RANGE (mph)	TIME (sec)	
0-30	6.2	
0-60	19.2	
30-65	16.3	24
40-60	9.9	11
50-70	13.5	14
DISTANCE TRAVERSED	DISTANCE (ft)	
FIRST		
5 sec	98	90
20 sec	1121	
W.O.T. ACCELERATION IN DIRECT GEAR		
SPEED-ENCOMPASSED	TIME (sec)	
50-60 mph	7.8	
50-70 mph	17.4	22
MAX. GRADE IN		
TOP GEAR @ 55 mph	6.1%	5.5%

5.0 RESULTS AND CONCLUSIONS

Primarily, a design has been developed for the manufacture of a safe family automobile for the middle 1980s, that can be utilized to investigate the applicability of safety requirements and their compatibility with environmental considerations. The design of the vehicle and the delivery of two pedestrian test articles and eight driveable RSVs to attest its performance are tangible results. In addition, certain conclusions can be drawn from the relative success achieved in the conduct of the program. During the development of the RSV from the Simca, major improvements were achieved in the capability of the vehicle to provide occupant protection. However, the detailed quantification of the life-saving benefits realized is not easy to assess.

One conclusion that can be drawn from the present program is that a significantly higher level of traffic safety is potentially attainable in the near future, albeit at an increase in purchase cost to the consumer. However, that initial expenditure should tend to be offset by the low operating cost and reduced expense related to accidents. Also, a vehicle like the RSV could be manufactured in facilities similar to those in current use. Further, materials required to build the RSV are generally available, and some manufacturing cost savings might be realized by design for particular recycling capabilities.[6] At the same time, however, some manufacturers might have to change to new products because of material substitutions attendant to new developments such as the urethane bumper system.

As previously mentioned, although the minimum goal of 65 kph (40 mph), driver survival of a barrier crash has been indicated, the desired 80 kph (50 mph) impact speed was not successfully attained. While structural response was generally good, the necessity of staying below the relatively low levels of accelerations needed to ensure non-aggressive performance in crush zones one and two resulted in higher than anticipated accelerations of the occupant compartment when zone three is crushed in order that the total crash energy be absorbed before the boundaries of the occupant compartment are seriously violated. It is clear that the degree of difficulty of designing a structure to be fabricated by current mass production techniques that simultaneously satisfies the various restrictions of the three crush zones within the space available in the RSV is greater than anticipated. Although 80 kph (50 mph) tests of experimental vehicles have successfully demonstrated compliance with FMVSS 208, such performance in a fully integrated, near production car like the Calspan/Chrysler RSV that also provides improved pedestrian safety as well as limited aggressivity is proving to be harder to achieve than thought previously. Since the 80 kph (50 mph) vehicle speed implies almost three times the energy of the current (to 1984) 48 kph (30 mph) regulation, it is questionable that such an increase in production vehicle capability could be available even by the end of the 1980s. It is not clear that even without hitches in the development there would be sufficient time to accomplish all the tasks that are associated with bringing out and proving a new production vehicle.

Development of air bag restraints on the RSV indicated a need for positioning the steering wheel very close to the driver in an almost vertical plane (horizontal column). Such a wheel position is sufficiently removed from those generally indicated to be satisfactory or preferred in tests of driver comfort, fatigue and vehicle handling that it is feared it would not be acceptable, particularly for large drivers. Hence, further research would seem to be required to resolve that delemma.

It has been our aim to provide in the RSV a rational basis for the formulation and assessment of motor vehicle regulations for the 1980s. Of course, only history can tell, but adoption of the features incorporated in the overall design of this car will, we feel, also provide an indication of the success of our program.

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