Section 3: Results of ESV/RSV Development

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Results of the United States Research Safety Vehicle Program

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ABSTRACT

The United States Research Safety Vehicle Program has been completed. Technical data on safety performance of two RSV designs is available. These data shows that the crash performance of these vehicles exceeded the performance of cars available on the market and that the aggressiveness of these RSVs to other road users was less than production cars. Steering and handling performance was not improved over production cars although some other advanced crash avoidance features were superior. Consumer interest in "safe" cars was evident in marketing studies. Program management problems were mainly associated with the technical specification of crash avoidance requirements, the lack of resources for a full demonstration program, and the inability to transfer technology to the market place.

INTRODUCTION

The United States Research Safety Vehicle (RSV) Program has been completed with fabrication and evaluation testing of complete RSV vehicles. Results, or products, of this seven-year program include an extensive amount of engineering data from a large number and variety of tests, design information on materials properties and processes, structural and mechanical component performance data, and systems integration data. Participants in the program also developed analytical methodologies as part of their specification and design studies. In addition to these technical outputs the RSV Program also compiled data on public attitudes towards automobiles emphasizing safety features.

This paper provides an overview of these results at the Program level for the Minicars and Calspan RSV projects. The evolution of the overall program plan and technical goals is briefly reviewed and the two RSV designs are summarized. Results are summarized for safety performance and design integration and the response of the general public to the RSV designs is presented as a market factor. Comments are offered on some of the major issues relevant to government sponsorship of such programs.

RSV PROGRAM

A project for an RSV-class passenger car was included in the original U.S. Experimental Safety Vehicle Program presented at the First ESV Conference (1)*. Described as an "Intermediate Sedan—3,000 pound class" the preliminary technical performance specifications for this project were distributed in 1973 prior to the Fourth ESV Conference. At that Conference the overall plan was reviewed (2) and many of the participants commented on the specification and on the program. In the implementation of the program many of these suggestions were accepted and incorporated either into the program or into one of the specific projects. The General Motors comments, for example, on the major issue of trading off crash protection against other design parameters and on the minor issue of lighting systems (3), were recognized and essentially adopted.

The Program objectives can be divided into two major areas (Figure 1). The first effort was the design and fabrication of experimental vehicles which would demonstrate improved levels of safety performance without negative effects on fuel economy or emissions, and, hopefully, with some enhancement of this performance. These vehicles were then used to assess the market acceptability

*Numbers in parenthesis are references.

- **Develop Experimental Vehicles To:**
  - **Demonstrate Improved Safety Performance**
  - **Improve Fuel Economy and Emissions Performance**
  - **Assess Market Acceptance of Safe Cars**
  - **Identify System Integration Problems**
- **Test Vehicles To:**
  - **Acquire Engineering Data for Rulemaking**
  - **Guide and Support Added R&D**

Figure 1. Research safety vehicle program—objectives.

of "safe" cars. The second major objective was to test these vehicles to acquire data for rulemaking support and to direct or assist other R&D efforts. This was done both at the total vehicle level and at the subsystem/component level (e.g., single beam headlights, soft bumpers). Throughout both areas, but primarily in the development work, a number of system trade-off and integration problems were identified and analyzed. This need to reconcile the frequently conflicting design demands of improved safety, better fuel economy, emission control, and economic feasibility in the market place was a key factor in initiation of the RSV Program.

Some of the underlying philosophy of the Program was that:

a. there should be continuous dissemination of information from the contractors involved,
b. industry should be substantially involved in order to assist in the technology transfer, whether voluntary or through regulation, and
c. safety was not viewed as a competitive selling feature and unless this could be changed voluntary improvement was unlikely.

Major phases or stages of the Program are shown in Figure 2. Five parallel studies were made in 1974 to define the broad concepts of the RSV and to further develop the performance specifications first proposed by NHTSA. As noted earlier, extensive review of the proposed specifications led to a number of changes in requirements. Two contractors, Calspan and Minicars, were then competitively selected to proceed with the design and development phase and subsequently moved on to systems integration and fabrication.

Frequent reports on the Program were presented as shown in Figure 2. These conferences were keyed to completion of major phases or milestones. References 4, 5, and 6 present results through the second phase and References 7 and 8 provide the contractors' status midway through the fabrication phase.

Evaluating testing began early in 1979 and was sup-

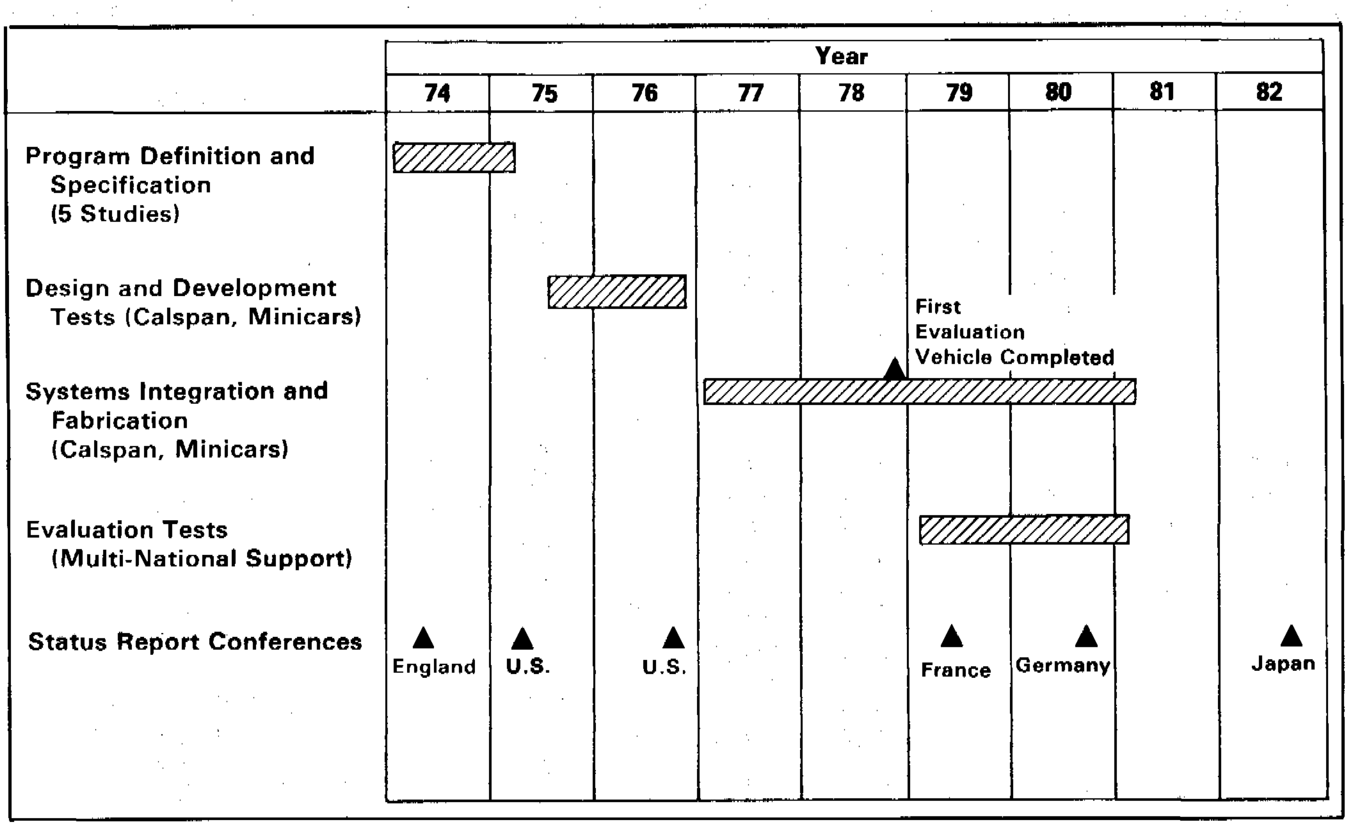

Figure 2. Research safety vehicle program—activity schedule.

	(U.S. $000's)
• Program Definition and Specification (5 Studies)	2,200
• Design and Development Tests (Calspan, Minicars)	7,000
• Systems Integration and Fabrication (Calspan, Minicars)	18,000
• Evaluation Tests	*2,900
Total	30,100

* Does Not Include Extensive Test Costs Incurred by Germany, Italy, France, United Kingdom, Netherlands, and Japan

Figure 3. Research safety vehicle program—program costs.

ported extensively by most of the countries and many of the manufacturers participating in the International ESV work. France, Italy, Germany, The Netherlands, the United Kingdom, and Japan all performed significant evaluation tests and reported on these tests beginning with the Seventh International ESV Conference in Paris in June 1979.

Costs of the RSV Program incurred by the United States are shown in Figure 3. Note that the total cost of $30 million does not include costs to other countries or the manufacturers who participated in the evaluation testing phase. For comparison, the cost of the U.S. Family Sedan ESV program was $15 million.

DESIGN SUMMARY

The design features of the Minicars and Calspan/Chrysler RSVs have been extensively reported earlier (5, 6, 7, 8, 9). Briefly, the Minicars approach, as shown in Figure 4, was to develop an all new body structure applying an innovative fabrication technology of foam-filled, thin gauge sheet metal sections for body structure. Designed from the basis of reducing societal cost from crashes, the design ended up at 2,550 pounds curb weight and achieved 50 mph barrier crashworthiness. Fuel economy achieved with the modified Honda engine was 29 mpg (City) and 41 mpg (Highway). The Minicar RSV is shown in Figure 5.

- **All New Vehicle**
- **Innovative, Near-to-Midterm Technology**
- **Societal Benefit Basis for Design**
- **2,550 Lb. Curb Weight**
- **Crashworthiness**
  - **Frontal: 50 MPH Barrier**
  - **Side: (Impact by Large Car) 35 MPH Each Car (90°)**
- **Fuel Economy**
  - **29/41/33 MPG**
  - **0.4/2.5/0.7 HC/CO/NO_X GPM**

Figure 4. Research safety vehicle program—minicars approach and performance.

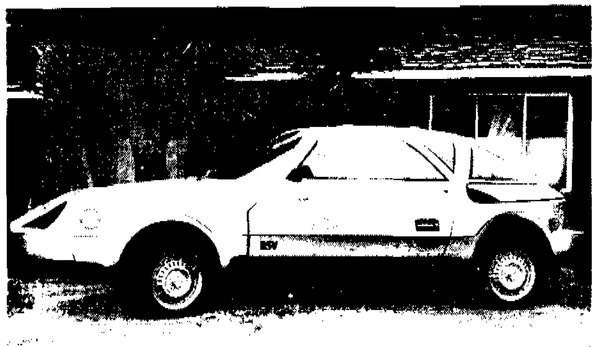

Figure 5. Minicar RSV.

The approach for the Calspan/Chrysler RSV is shown in Figure 6. This RSV was evolved from a 1976 Model Year Chrysler Simca and thereby represents a conventional, near-term State-of-Art technology. Extensive use was made of simulation analyses in the structural design process. The RSV, as shown in Figure 7, weighed 2,675 pounds. Major crash performance levels achieved were 40 mph Frontal Car-to-Car protection and 34 mph Side protection. The turbocharged engine with 5-speed gearbox and feedback carburetor installed by Volkswagen provided 26 mpg (City) and 42 mpg (Highway) and reduced emissions significantly over the standard Omni/Horizon engine installation.

PERFORMANCE RESULTS SUMMARY

Nearly 60 complete RSV test vehicles of various types were built and tested throughout all phases of the RSV Program. Many different types of tests were performed—aerodynamic drag, handling, braking, crash repairability, low speed damage protection, and others, as well as high-

- **Modification of Production Vehicle (Chrysler Simca)**
- **Conservative, Near-Term Technology**
- **Analytical Basis for Design**
- **2675 Lb. Curb Weight**
- **Crashworthiness (Car-to-Car)**
  - **Frontal: 40 MPH (Each Car)**
  - **Side: 35 MPH (Each Car, 90°)**
- **Fuel Economy/Emissions**
  - **STD Engine** { **23/34/27 MPG**; **0.5/4.87/1.03 HC/CO/NO_X GPM**
  - **T/C Engine** { **26/42/32 MPG**; **0.13/2.1/0.9 HC/CO/NO_X GPM**

Figure 6. Research safety vehicle program—Calspan/Chrysler approach and performance.

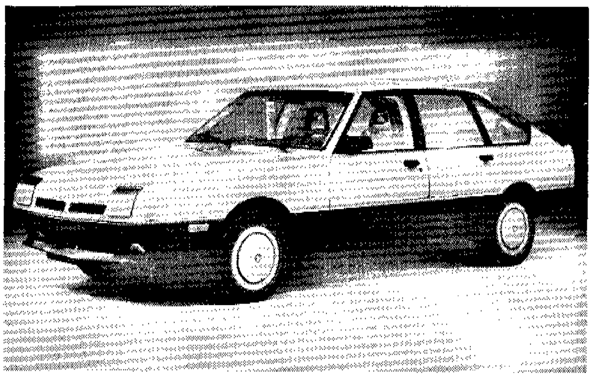

Figure 7. Calspan RSV

speed car-to-barrier and car-to-car crash tests. Detailed results of these tests have been reported at previous International Technical Conferences on Experimental Safety Vehicles beginning with the Sixth. This report summarizes these results at the Program Level.

OCCUPANT PROTECTION

Both RSVs developed crashworthy structure and integrated these structures with automatic restraints, padding, seating systems, and other body and chassis elements to provide safety performance as shown in Figure 8. Using either conventional (Calspan/Chrysler) or innovative (Minicars) technology as described earlier, these vehicles were able to demonstrate occupant protection in various crash modes.

Both RSV designs integrated automatic restraint systems for drivers and front seat passengers. Two distinctly different air bag designs were developed for the drivers. The Calspan/Chrysler RSV driver restraint incorporates a steering wheel-mounted air bag with a pyrotechnic inflator, porous nylon bag, primary and back-up crash sensors, and a dash-mounted diagnostic box. Knee blockers are used but an active lap belt is available. The Minicars RSV driver restraint system has a dual air bag configuration mounted in the steering wheel assembly. The inner and outer bags are cylindrical and are constructed of low permeability nylon. Venting in these bags is accomplished by the fabric porosity. This system also has inflators, primary and back-up crash sensors, and a diagnostic system. The system generally works with a collapsible steering column and additional knee restraints. Satisfactory structural integrity, controlled collapse of the front end, and adequate energy dissipation are achieved through proper design of the frontal structure.

It was in matching front structure performance with restraint performance and in integration into the RSVs that most effort was required.

The Calspan RSV system has demonstrated protection up to 80 mph closing speed in head-on crashes against equal weight cars. The Minicars RSV system users will be protected in frontal impacts as severe as a 50 mph barrier crash. Of approximately 9,500 driver fatalities that occur annually, in the U.S., it is estimated that almost 6,200 of these could be eliminated if all cars were equipped with similar systems.

The Minicars RSV also uses a dual bag concept for automatic passenger restraints. Two bags separated by a thin membrane serve as a torso and head cushioning device. The torso bag is smaller than the head bag and the volume and design features of each are tailored to meet chest and head loading requirements. The system consists of dual chamber bag, solid propellant inflator, crash sensors, energy absorbing dash, and knee pad. In the event of a crash the torso bag fills very quickly and maintains a high pressure. As the torso comes in contact with the bag, the gas is forced into the bag for the head through a vent in the membrane. Then the upper bag inflates and retards the head as it starts to move. The system includes passenger knee restraints.

The Calspan/Chrysler RSV uses an inflatable torso belt system for passenger protection. The belt uses an auxiliary drive system to automatically position the belt on the passenger. Knee blockers or an active lap belt are used in conjunction with the belt.

An inflatable belt distributes the crash loads on the occupant torso over a large area thereby reducing chest injuries. It also cushions the head and restrains occupant forward motion. The same system functions as a conventional shoulder belt system when low-level crash forces are encountered as in minor accidents which do not deploy the air belt. A pyrotechnic inflator automatically inflates the belt to an 8-inch-round bag during crashes. Force limiting webbing is used on the ends of the belt to limit the belt loads to 2,000 pounds. An advantage of this type of system is that it is not unique for any particular model and therefore can be used in a full line of production car models, thereby reducing costs. The air belt is obviously more susceptible to consumer complaints about discomfort, inconvenience, and appearance than are air bags.

The RSV Side Impact Occupant Protection Systems

- **Developed Both Conventional and Innovative Structures for Front, Side, Rear, and Rollover Crash Protection**
- **Demonstrated Automatic Protection For:**
  - **80 MPH Car-to-Car Frontal Crashes With Conventional Structures Technology**
  - **50 MPH Frontal Barrier Crashes With Innovative Structures Technology**
- **Demonstrated Car-to-Car Side Crash Protection at 50 MPH Closing Speeds**
- **Demonstrated Rear Crash Protection at 45 MPH With Conventional Technology — No Fuel Leakage**

Figure 8. RSV results summary—occupant protection.

utilize improved door structure, strengthened pillars, interlocks between the door and the vehicle structure, door beams, and interior padding. The purpose of these components is, first, to reduce the gross deformation of the passenger compartment caused by an impacting vehicle, and secondly, to control the impact forces on the crash victim.

The Calspan RSV Side Structure utilizes conventional design combined with application of high-strength materials to prevent the intrusion into the occupant compartment. Having reduced the intrusion, the occupant impact forces are controlled by utilizing foam door trim pads which enclose aluminum honeycomb. As the door is moved inwards towards the occupant, the honeycomb and padding deform to limit and control the forces imposed on the occupant.

In addition to the design features of the Calspan RSV, the Minicars RSV embodies a heightened door sill. The purpose of this sill is to interact with a striking vehicle's front structure, thereby reducing the magnitude of collision force applied to the door itself.

The Calspan and Minicars RSV Side Impact tests have demonstrated that front seat dummies could survive in a car-to-car crash at up to 50 mph closing velocities with each vehicle traveling at 35 mph. Survival is defined as injury measures on the dummies being less than those required by Federal Motor Vehicle Safety Standard 208. If all vehicles in the U.S. car fleet provided front seat occupant protection in side impact accidents at speeds of 50 mph, fatalities would be reduced by approximately 40%, assuming no change in the accident pattern. This is based on an analysis of the side impact test data of the Calspan RSV.

Rear crash protection of the Calspan RSV was gained not only by modest strengthening of the rear structure but also through careful redesign of the fuel tank and fuel filler systems. The tank was strengthened and moved forward on the vehicle and attached with wrap-around straps. The fuel filler neck was also moved forward over the rear wheel and out of the impact zone. These steps were essential to reducing fuel leakage in rear impacts.

AGGRESSIVENESS

A principal requirement of all Experimental Safety Vehicle research has been the reduction of aggressiveness toward other road users—pedestrians, bicyclists, and cars. RSV results in this respect are summarized in Figure 9.

- **Demonstrated Technology To Reduce Pedestrian Injury Levels at Impact Speeds Up to 25 MPH**
- **Demonstrated Low Speed Damage Protection to Struck Cars up to 8 MPH**
- **Demonstrated Technology To Reduce Injury Levels of Struck Car Occupants in Side Crash Tests at 50 MPH Closing Speeds**

Figure 9. RSV results summary—aggressiveness.

Low speed aggressivity toward pedestrians or other cars was achieved by designing a "soft nose." This soft nose design developed for the RSVs consists of a high density reaction injection molded (RIM) skin which encloses a low density foam. Engine cooling air slots are provided, together with cut outs for headlamps and parking lamps. The shape of the unit, and the foam properties, can be tailored to meet specific design requirements. With this concept, vehicle aggressivity toward both pedestrians and other vehicles is simultaneously reduced. This front end design provides clear cut reduction of pedestrian injuries compared to current front-end designs. It is also less aggressive in low speed (less then 10 mph) impacts with other cars. The weight of the unit, as designed for the Calspan RSV, for example, is approximately 35 pounds; one half that of a conventional bumper, grill, valance, etc., which it replaces.

The National Highway Traffic Safety Administration has estimated that up to 13,000 pedestrian injuries would be reduced in severity and up to 340 pedestrian fatalities per year would be eliminated if the entire U.S. car fleet was equipped with soft bumpers.

High speed crash aggressivity reduction, of course, involves front end structural design rather than just the soft nose. In a series of paired car-to-car tests the RSVs showed the ability to reduce the level of dummy measurements in the car struck in the side by the RSV as compared to the paired car. Such benefits in reduced aggressiveness are, of course, gained at the expense of occupant protection and the RSV design development and evaluation tests provide valuable data for understanding this concept.

In the paired tests the reduction in front seat dummy measures was significant. Chest and pelvic accelerations were reduced 30 to 40%. Rear seat dummy measures were not improved, however, to the same degree and this behavior has not yet been explained.

ACCIDENT AVOIDANCE

A number of well-established concepts related to accident avoidance were integrated into the RSVs. Some of these are noted in Figure 10. Anti-lock brake systems, flat-proof tires, low tire pressure warning systems, and high level rear lighting were used but were not specifically evaluated under this program. A light-weight, single beam headlight system was developed by CIBIE for the Calspan RSV and was evaluated under a separate NHTSA project

- **Integrated Crash Avoidance Subsystems:**
  - **Anti-Lock Brakes**
  - **Advanced Lighting**
  - **Conspicuity Stripes**
  - **Tires**
- **Developed Radar-Activated Crash Mitigation System**
- **Identified Issues With Crash Avoidance Performance Specifications**

Figure 10. RSV results summary—accident avoidance.

(10). A radar-activated Crash Mitigation System was developed for the Minicars RSV but was not extensively evaluated beyond the design development phase.

Probably the most important contribution of the RSV Program to Accident Avoidance was to focus attention on the problems of crash avoidance specifications. While the RSVs met the technical specifications for steering, handling, and braking performance that had been proposed and accepted at the beginning of the Program, they were considered by many to be inadequate in this performance category (11). The quantified RSV performance requirements were not sufficient or complete enough to avoid this negative judgment. Further definition of these requirements must be made in future R&D work.

SYSTEMS INTEGRATION

A prominent feature of the planning for the RSV Program was the broad objective of examining the tradeoffs and integration demands of the various subsystems or requirements. Indeed, early descriptions of the Program focused on the so-called "S3E" concept of balancing *S*afety, *E*nergy conservation, *E*nvironmental protection, and *E*conomy of purchase and operation for the consumer. The principal focus of these efforts became the development of weight efficient body structures using either conventional production processes with new applications of materials, or the development of the innovative Minicars structure. Very limited engine, drive line, and emissions control development was carried out in this Program and so the tradeoffs and integration were limited to packaging the various power plant components and subsystems.

Some other integration efforts were made on Safety/Fuel Economy issues as shown in Figure 11. Aerodynamic tests were carried out on the RSVs not only to explore external shapes but also to investigate specific details of front dams, external mirror size and shape, wheel covers and wheel parts, etc. It was on the basis of such data for example, that decisions were made to use headlight covers and small external mirrors that failed to show FMVSS compliance, in order to enhance fuel economy at the expense of some *possible* degradation of safety performance.

- **Designed Weight Efficient Conventional and Innovative Structures — 2500 to 2700 Lbs.**
- **Identified Aerodynamics Benefits/Tradeoffs**
  - **External Shapes**
  - **Design Details: Front Dam, Mirrors, Glazing, Spoilers**
- **Methodology for Systems Optimization**

Figure 11. RSV results summary—systems integration.

Finally, the development of analytical methodologies for design optimization were initiated in the RSV Program. Simulation methodologies for vehicle level and fleet level analyses were started in the first phase of the Program and continued expansion of some of these is continuing. Other methodologies were developed for projecting vehicle engineering characteristics and for cost-benefit assessments.

MARKET FACTORS

A summary of RSV work in the general area of market factors—price to the consumer, safety benefits, and acceptance of the concepts—is given in Figure 12. Throughout all phases of the Program an attempt was made to estimate the MSRP (Manufacturer's Suggested Retail Price) for the RSV designs. In some cases, automatic restraints for example, alternate price estimates were obtained from sources other than the RSV designs. As expected, the cost estimates for some systems varied by as much as 3 to 1. Obviously, the baseline for price estimates varied, different technological assumptions were made, and in fact, technology has changed over the course of the Program. Slight variations in performance could be accepted for reduced price. In fact, simplified versions of

- **Estimated MSRP for RSV Designs**
  - **Range of Price Estimates**
  - **Evolving Technology (Materials, Designs)**
- **Estimated Crashworthiness Benefits**
  - **Evaluation Technology (Dummy, Test Modes)**
- **Assessed Consumer Reaction to RSV Concepts**
  - **Market Research (Focus Groups)**
  - **Safety Valued at $300 to $1500**

Figure 12. RSV results summary—market factors.

such RSV concepts as side door interlocks and secondary hood latches are now appearing in production cars.

Similarly, various estimates of crash benefits were made. These are obviously heavily dependent on the human surrogates and test modes utilized in the evaluations. The improved designs for dummies now being utilized in side crashes would probably alter both the RSV designs and the anticipated benefits. It is NHTSA's judgment that substantial reductions of fatalities and serious injuries could be achieved with RSV-type structures and restraint/padding systems.

The RSVs were widely exhibited to the general public and to technical audiences. Media interest was high and, in fact, TV and magazines are still reporting on the Program. Public response covered a wide range of issues ranging from technical details to practical considerations of ownership to the philosophy of U.S. Government sponsorship of such programs. While classification of the responses is difficult, they signify a broad interest in highway safety and 95% of respondents who commented on market availability indicated a desire to purchase such safe cars. Such response obviously correlates closely with expected price.

A more concentrated marketing survey was made with the Minicars RSV using focus group discussions (12). Twenty-three such groups were assembled in 10 cities across the U.S. While results are not statistically valid the research did show an increased value of safety features after some education on automobile safety performance. Price and fuel economy (the study was conducted in 1980) were the strongest factors in purchase decisions.

A conclusion might well be that consumers are much less informed on safety than on fuel economy, comfort, or styling and that increased awareness of safety could alter these priorities.

PROGRAM MANAGEMENT

Finally, a number of program management issues became apparent during the eight-year span of the program. These are listed on Figure 13. One major issue was the incompatibility of goals and objectives with the resources available, and the variation in some objectives with changing administrations. Funding and schedules were clearly not compatible with the ambitious goals for emissions and fuel economy performance.

Similarly, as the emphasis changed from one of technical evaluation of advanced safety concepts to total demonstration, resources were insufficient. For example, a major problem in the Calspan/Chrysler RSV active safety or handling performance was the "cramped" driver environment. This occurred because resources were not available to widen the base Simca when side crash padding protection was added and the interior space was reduced.

RSV design reviews were lacking in two important areas. There was insufficient emphasis on production technology projected by the RSV designers and there was a failure to explore necessary parallel changes in operational requirements for such things or license plates, tax or inspection stickers. The soft front bumpers and modified windshields would necessitate changes that, while considered feasible, were not explored or widely recognized and acknowledged.

- **Ambitious Goals, Objectives**
  - **Fuel Economy, Emissions Goals**
  - **Demonstration vs Evaluation**
  - **Inadequate Resources**
- **Inadequate Design Assessments**
  - **Production Technology**
  - **Operational Requirements**
- **Wide Dissemination of Information**
  - **Technical Conferences**
  - **Media**
- **Inadequate Technology Transfer**

Figure 13. RSV results summary—program management.

These deficiencies in design reviews were partly overcome, however, by the frequent wide dissemination of program information to the technical community. In the U.S. the SAE included papers on the RSVs and technical displays in almost all of their national meetings from 1976 through 1980. Internationally, the ESV conferences and displays continued to provide the means for technical data exchange. General dissemination of data to the nontechnical public in the U.S. has been discussed earlier.

And, finally, a disappointment of the RSV Program Management has been the inability to transfer the technical results either to the market place or even to the NHTSA rulemaking engineers. Only one element unique to the RSV design—the St. Gobain "Securiflex" (TM) windshield—has been considered for rulemaking action. None of the fuel economy/safety tradeoff issues (e.g., headlight covers, external mirrors) are being considered for change. Utilization of the vast amount of engineering data has been minimal.

CONCLUSION

The RSV Program was responsible for acquiring a great deal of technical data on the safety performance of complete integrated vehicles in a wide range of crash conditions. The crash performance of these test vehicles exceeded the performance of cars available on the market. Similarly, the aggressiveness of these RSVs to other road users—cars and pedestrians—was less than production cars. Crash avoidance performance was not improved over production cars and in some aspects was considered less satisfactory. In the U.S. there would appear to be some consumer demand for "safe" cars as determined through market assessments with the RSVs. Transfer of improved safety technology to production cars is not being accomplished.

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Minicars RSV: Results of Angled Barrier and Headform Impact Tests and a Comparison with Those of the Calspan RSV and Chrysler Alpine

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ABSTRACT

A Minicars RSV was impacted into a 30° wood-faced angled barrier at a speed of 60 km/h and subsequently its interior was impact tested using a free flight headform. The results of these tests are compared with those from similar tests on the Calspan RSV and a Chrysler Alpine car which was the baseline production car used to develop the Calspan RSV. All the tests were carried out at MIRA.

In the angled barrier test the Minicars RSV met the requirement of ECE Regulation 33 with regard to occupant survival space. There were two Part 572 dummies in the front seats. Despite a delay in the deployment of the drivers airbag, all the dummy acceleration and femur loads complied with the requirements of FMVSS 208. The car met the full system integrity requirement of FMVSS 301 with regard to the 30° angled barrier impact but failed to meet the static rollover requirements because of a minor design error in the fuel filler.

The headform tests showed the need for more protection in secondary vehicle impacts when the occupants are not fully restrained.

The comparison of the results from the different cars showed an improvement in survival space and occupant injury criteria of the RSV designs over the production car.

INTRODUCTION

This is a report of a frontal angled barrier crash test of the Minicars Research Safety Vehicle (RSV) (Ref 1) followed by a series of interior headform impacts. The tests were carried out at the Motor Industry Research Association (MIRA) (Project officers Messrs. B F Smith and K Clemo) upon instructions from the Transport and