5. The time required to travel a fixed distance under full acceleration was shorter for an average 1979 automobile and a poorly performing 1981 model than for the assumed 1937 design passenger vehicle. Over a given distance, the times were 33 percent shorter for the 1979 automobile and 23 percent shorter for the 1981 model than for the design passenger vehicle. Thus, modern automobiles can accelerate across and clear an intersection in less time than the 1937 automobile. Consequently, the intersection sight distance criteria given in the AASHO Blue Book remain appropriate for current use. However, the acceleration capability of new cars should be monitored at regular intervals in the future should vehicles powered by alternative fuels or energy sources become as popular as it has been widely projected.

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Federal Government and Integrated Vehicle Development: U.S. Experience

R. K. WHITFORD

Three integrated vehicle-development programs sponsored by civilian mission agencies in the federal government are critically reviewed. A brief historical background and some critical reflections are provided for the Transbus, Experimental Safety Vehicle, and Near-Term Electric Vehicle programs. The purpose of the assessment was to determine the lessons learned that might be applied in future programs. Funding limitations, relationships with industry, overly stringent specifications, lack of planning, competition (parallel contracts), international participation, and government involvement in commercialization are factors that are examined. Although all are important, planning the project following an in-depth requirements analysis and carrying it through under a cooperative partnership with industry appear to be the most important for future programs.

Vehicle research and development (R&D) programs initiated by the federal government are sometimes viewed by the private sector with alarm and doubt. Three recent U.S. vehicle programs are critically examined in this paper in order to assess our success in the programs and to determine from the experience what lessons might be applied to future programs. Each vehicle program chosen reflects government response to a different perceived public requirement or need.

1. The Transbus program was initiated to generally improve bus aesthetics, passsenger amenities, and the special mobility needs of the elderly and handicapped by developing a bus with lower overall floor height and improved boarding and discharge capability. Because the government grants a significant percentage of the capital for new bus purchases (50-80 percent), it was planned to improve buses by using the federal grant power to aggregate the market demand and by requiring grant recipients to purchase buses according to Transbus specifications.

2. The Experimental Safety Vehicle (ESV) program and its follow-up program, the Research Safety Vehicle (RSV), had as their primary goal the support of automobile safety rulemaking. Basically, the program was initiated to determine whether crashworthiness could be improved through integrated vehicle design and, if so, at what cost. The initial program dealt with large cars; the following program, with small vehicles (less than 3000 lb). The latter program also dealt with concerns for reduced emissions and enhanced fuel economy.

3. The Near-Term Electric Vehicle program was to be one of several developments that, if successful, would help the U.S. citizen retain a high level of personal mobility and simultaneously meet the national goal of reducing petroleum use. Gasoline price control and perceived high technological risk kept commercial electric-vehicle R&D at a low ebb until Congress initiated a program in 1976 to push electric vehicles. The Near-Term Electric Vehicle program was one major portion of that R&D effort.

The major results of this assessment are found in the concluding section of the paper, entitled Lessons Learned. These lessons should be taken into account in planning any new program of vehicle R&D leading to commercialization and public use.

ROLE OF GOVERNMENT IN R&D

The goals of R&D expenditures in the federal sector are considered here. Expenditures for near-term technology can be evaluated by standard benefit/cost methods. In contrast, longer-term R&D is less amenable to quantitative evaluation and depends on political values and insights at the time of authorization and appropriation. Furthermore, such programs in the civilian mission agencies are often funded on a year-to-year basis and must compete in each budget cycle with other priority programs, often new ones resulting from changes in political leadership.

Federally financed R&D programs are usually designed to meet one of five basic government functions (1, pp. 305-333):

1. They are intended to support operational activities that are the direct responsibility of the federal government, e.g., national defense, surveillance of the seacoast, and air traffic control.
2. They support the regulatory process, either in determining the cost and effectiveness of promulgation or in developing the procedures, tools, and instruments (such as the ESV) needed for effective enforcement. The studies and experimental measurements made before the automotive fuel economy regulation or aircraft noise regulation were essential; compliance test procedures were necessary for the enforcement of automobile emission control regulation.
3. They undergird grants made to state and local governments by providing research and data to aid decisionmaking or by stimulating industry to provide needed developments. One example is the highway research carried out by states under the National Cooperative Highway Research Program (also the Transbus program).
4. They augment private-sector investments to spur R&D in particular areas of national concern; e.g., recent direct investments in energy R&D and individual tax incentives for solar heating that created a market (also electric-vehicle research).
5. They help meet general economic and social needs in areas where the major responsibility lies with the government and where the private sector lacks sufficient incentive and/or resources to make adequate investment. The U.S. space program and basic and applied research programs that support scientific and engineering activities in universities are examples.

The government uses a variety of mechanisms to achieve the desired result in each of these categories; basically these are contracts, usually fully funded, with full government specifications and with the R&D results made available to all who wish to use them. Some contracts, however, are of a cost-sharing variety and allow for protection of proprietary development depending on the sharing arrangement. For basic research, the government often grants the money to be used in a more discretionary way. In addition, the government may also attempt to subsidize (often through tax structures) some R&D by rewarding the commercialization of a product or products.

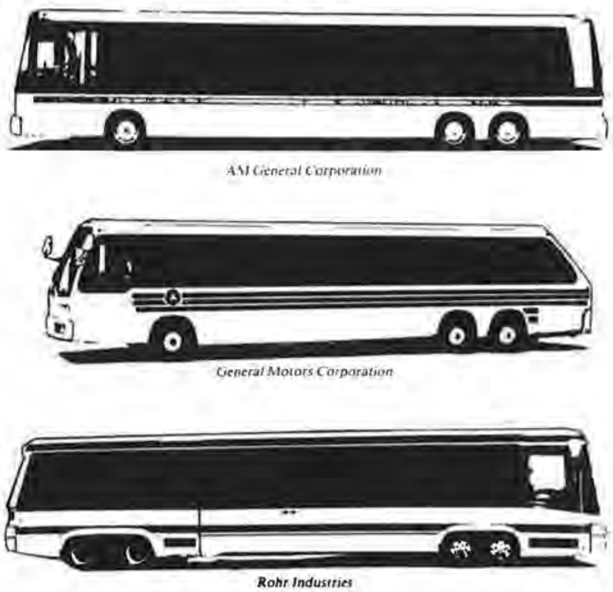
TRANSBUS

Background

Transbus, an UMTA R&D program, was initiated in 1971 with the stated purpose to (a) improve passenger comfort and ride quality, (b) reduce operating and maintenance costs, and (c) provide special features to facilitate its use by the elderly and handicapped. The special features to be developed were a low floor, two-step entry, kneeling capability, ramp or lift to provide for wheelchair entry, increase in front door width, and provisions for wheelchair locks and turnaround. Other system-level improvements included service life, curb visibility, and fire resistance. The desires of the transit agencies were communicated to UMTA through the Bus Technology Committee of the American Public Transit Association. [Before 1965, General Motors Corporation (GMC) had a virtual lock on the bus market--an 85 percent share. GMC's main competition, Flxible, accounted for the remaining 15 percent. Following a U.S. Department of Justice suit in 1965, GMC agreed to allow other companies to buy major bus components at interdivisional rates. AM General entered the bus-manufacture business in 1971.] Three contracts were awarded (to GMC, Flxible, and AM General) in 1972 for the development of a prototype Transbus to be followed by 100 preproduction models for service testing. Nine prototypes (three from each manufacturer), as shown in Figure 1, were delivered in 1974; demonstrations were held around the country in 1975. There followed a month-long demonstration in revenue service in each of four cities. The purchase of the 100 preproduction units was canceled in 1975 when UMTA announced that, in lieu of design specifications, it would develop a performance specification for low-floor urban buses that would have performance requirements related to safety, accessibility for the elderly and handicapped, low maintenance, high performance, and economical operation. Hearings were held and specifications developed from 1976 to 1978.

In 1977, the Secretary of Transportation issued a Transbus mandate that all full-sized buses purchased with federal aid after September 1979 were to comply with Transbus specifications. In early 1979, three cities formed a consortium to obtain purchase bids on 530 buses to be built to meet Transbus procurement specifications. [The Transbus Consortium included the Southern California Rapid Transit District (Los Angeles), Metropolitan Dade County (Miami), and Southeastern Pennsylvania Transportation Authority (Philadelphia). Unfortunately, each transit authority had so many individual requirements that many potential advantages of the multiple

Figure 1. Prototypes for Transbus program.



bid were nullified (2).] No bids were received by May 1979, the bidding deadline. In August, a delay in the effective date for compliance with Transbus procurement specifications was issued. At this time, the Transbus Procurement Request has been permanently shelved.

Although some costs are unknown, for example, those spent by industry in response to the mandate or in preparing for competition, about $30 million was spent by the federal government on the development project for the nine buses.

Reflections

The Transbus program (3, p. 21) was for a vehicle design stimulated by the government in an attempt to solve a dual mandate of improved bus performance and improved accessibility for the elderly and the handicapped. The first goal was already being considered by GMC and Flxible, which were in the process of introducing improvements in their existing "new-look" bus designs. They were also involved (encouraged by UMTA) in an evolutionary product design called the advanced-design bus (ADB).

The major departure in Transbus over the ADB was the low floor, which created potential problems in the technology of axle and drive-train design, tire design and wear, and obstruction clearance. In addition, the estimated Transbus cost represented a 60 percent increase in purchase price over the "new-look" bus and 50 percent over the estimates for the ADB, which in fact incorporated many of the passenger amenities and safety and operating capabilities desired in the Transbus. Relative to the ADB, Transbus as specified has one or two fewer seats, is about 2 percent less fuel efficient, and costs more to buy, operate, and maintain (4, p. 10).

The Transbus procurement request specified the use of several unproved, risky technologies. These, coupled with onerous warranty terms for which the bidders had to assume all the risk and including guarantee of service life and performance, were key reasons for the lack of bids. No doubt the unproved provision for the elderly and handicapped, which suggested the steep ramp design or lift operation, presented potential product liability. (To provide reasonable egress, the ramps had to be either too long or too steep.) Foreign competition was also kept out of the bidding because of the buy-American policies that existed at that time. Finally, there was no indication that any advantage was taken of European experience with low-floor, low-entrance buses.

The orderly process from prototype to production of a new product takes a predictably long time, especially when some development and extensive testing of key subsystems and components are needed. If adequate tests are not planned early in the R&D phase of the program or are not carried out, the price must be paid in the operational phase. In Transbus, for example, the cancellation of a second phase, i.e., the purchase and extensive testing of 100 preproduction models, caused a major gap in the orderly movement from R&D to production.

In addition, the timing was inopportune in that the Transbus program occurred just at the time major manufacturers had completed, and were attempting to absorb, investments in their ADB product. These circumstances, coupled with uncertainty about several changes in U.S. Department of Transportation (DOT) leadership, government regulations, and the nature of the bus business in general, provided a poor climate for any significant additional investment.

Another inhibiting item was the relationship of the product to the real needs of the elderly and handicapped. Other potential alternatives did not provide for mainstream access for those of the elderly and handicapped not already using transit. Later market studies indicated that the Transbus capability did not guarantee the use of the system. Bus-stop waiting, fear of crime, and nonbus movement from bus stop to other destinations were equally significant deterrents to potential elderly and handicapped users. One study showed that the additional users of the system would represent only 4 to 6 percent of the elderly and handicapped market. There was also political pressure. At one point, when UMTA stated that a low-floor bus could be introduced on an evolutionary basis, litigation was initiated by representatives of the elderly and handicapped lobby to reverse the decision. Apparently missing at the outset was a valid study assessing the usefulness and cost-effectiveness of a variety of alternative ways to enhance the mobility of the elderly and handicapped.

INTEGRATED SAFETY VEHICLES

Integrated-vehicle R&D with specific safety requirements was initiated in 1968 under the ESV program. R&D continued through the late 1970s for a second vehicle, the RSV. Sponsored by NHTSA and its predecessor agency, the National Highway Safety Board (NHSB) (NHSB became NHTSA in 1970), the primary goal of both programs was to evaluate improved safety concepts, especially crashworthiness and occupant-protection systems.

Until 1962 safety standards for automobiles were not part of federal statutes. In 1962 and 1963 federal standards were enacted for brake fluids and seat belts, respectively. These were followed by a more complete set of standards. (Known as the Roberts Law, PL 88-515 resulted in 17 standards established by the General Services Administration for government-purchased automobiles.) In 1966 PL 89-563 enabled NHSB to issue standards for all motor vehicles. Twenty-two Federal Motor Vehicle Safety Standards (FMVSS) were issued, to be effective in 1968. The law included a series of studies aimed at developing a research data base to support further rulemaking efforts. The vehicle program that was established was called the Family Sedan Experimental

Safety Vehicle program (better known as ESV). The four basic objectives of the ESV program were (5, p. A-7; 6)

1. To determine the technical feasibility of making significant "quantum jump" advancements in automotive safety performance;
2. To stimulate public awareness of the injury reduction potential and associated economic advantages of advanced automotive safety;
3. To encourage the automotive industry, both domestic and foreign, to increase its level and effort in motor vehicle safety research, and to accelerate the integration of advanced safety systems into production vehicles; and
4. To establish a technical base for the development of improved motor vehicle safety standards.

The ESV program, which spanned the years 1968-1974, included the following significant developments:

1. Four U.S. companies provided family sedan prototype cars designed to meet stringent safety specifications, especially 50-mph front-barrier and rear-crash and 70-mph rollover protection. Major automobile companies, GM and Ford, provided ESVs for a contract cost of $1. Chrysler was a subcontractor to Fairchild.
2. These vehicles underwent extensive testing in order to evaluate crash injury-reduction systems (without active restraints) and accident-avoidance technologies such as improved braking, handling, and visibility.
3. Because all cars required a 20 to 30 percent weight penalty to meet the specification, NHTSA was able to develop an improved understanding of the relationship of safety increases to fuel consumption and vehicle costs.
4. As a result of the fuel embargo, which occurred during the ESV program, there was an increasing interest in smaller, lighter cars as well as major concern about the safety of such cars. As a result, a shift from the family sedan ESV to the RSV (3000 lb or less) occurred in 1974.
5. A series of international agreements for mutual cooperation were instituted between 1970 and 1972 with Germany, Japan, the United Kingdom, Italy, France, and Sweden. International ESV conferences were held beginning in January 1971. In parallel with the U.S. program, some 14 foreign ESV-type models were built by companies in the six participating countries, often to less stringent specifications but with considerably improved safety. Several countries also invested significant resources in test tracks and test facilities for evaluating safety performance. The cost of the international program has been estimated at $150 million (7, pp. 2.0-28 through 2.0-30).
6. An estimated $25 to $30 million was spent in the United States, about half in public funds and half in private funds.

The RSV program was initiated in 1974. It was to be R&D relevant to the cars of the 1980s and to retain and expand the positive features of the ESV program. Practicality of design (exercised through mandatory weight limitation) was stressed. The early involvement and participation of the automobile industry, both domestic and foreign, was also to be sought.

Its goals, similar to but broader than those for the ESV, included enhanced fuel economy, reduced emissions, and consumer consideration. They were based on a more thorough initial study of traffic accident causation and characterization. Studies also included a review of aggressiveness in collisions and pedestrian/cyclist accidents. Engineering data from the evaluation and test of the RSV were to be used to assist in the development of FMVSS for the mid-1980s.

Five companies received contracts to provide phase-1 data characterizing traffic projection and preliminary design for a range of possible vehicles (3000-lb maximum) to meet such traffic conditions. Two companies with vastly differing approaches were selected to design and fabricate models in the 3000-lb range. One approach was more conservative and evolutionary (the Calspan/Chrysler team), whereas the other involved more innovative features (minicars). The overall RSV program cost about $30 million.

Ten models of each vehicle have been delivered and have undergone or are undergoing testing. Unfortunately, no summary report is available at this time. The minicar approach resulted in a car weighing about 2200 lb and showed many unique advantages and safety approaches in the use of very lightweight materials and design innovations. In addition, NHTSA had a six-passenger family sedan built that used essentially GM styling. That one prototype was used to attempt to stimulate the industry by showing what could be done with innovative technologies.

Although the program had an overall negative result (that is, meeting the 50-mph crash-barrier capability necessitated severe weight penalties), the initial ESV program achieved the major benefit of focusing the automotive industry, both American and foreign, on a broad set of safety concerns. The expenditure of more than $30 million has resulted in much improvement in vehicle safety and hence a reduced loss of lives. Although not due solely to the ESV program, since 1967 there has been a dramatic improvement in automobile-occupant protection as shown by the sharp reduction in fatalities per accident per vehicle mile traveled (Figure 2).

The RSV work added a new dimension, namely, the trade-off between safety and fuel consumption, particularly in smaller, lighter-weight cars. It is not clear, however, that the effort had much to do with rulemaking as such, except to show that there was at least one technology available where fuel economy improvements could be incorporated in cars that would have a higher degree of crashworthiness.

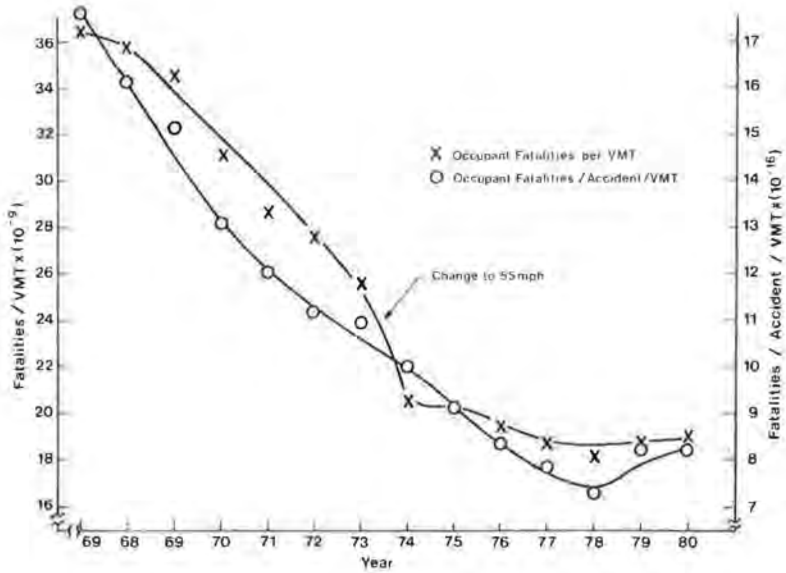
The six-passenger lightweight vehicle, which used the minicar design, was apparently constructed primarily for political purposes. It was used as an attempt to prod the automobile manufacturers. Industry's reaction to that approach probably helped to spell doom for the program in the current administration. At this time there is no further budget for the integrated-vehicle R&D program. Unfortunately, the elimination of this program occurs at a time when such integrated-vehicle R&D could be important to improve the safety potential of very small cars, especially in light of their poor safety performance (8). Only an integrated, total-vehicle approach will improve understanding of how to build maximum passive safety capability into a small car.

The ESV/RSV program was unique in that no previous single program had done more to advance automobile safety on an international basis. This is especially important when one considers the worldwide construction of test facilities and test vehicles that ensued.

ELECTRIC AND HYBRID VEHICLES

In September 1976, Congress enacted Public Law

Figure 2. Safety data related to occupant fatalities.



94-413, the Electric and Hybrid Vehicle Research Development and Demonstration Act of 1976. The act was to accelerate the development and to demonstrate the commercial feasibility of electric and hybrid vehicles through government-sponsored R&D, demonstrations, and financial incentives. A major portion of the program was the Near-Term Electric Vehicle Program, whose goals were to (9)

1. Determine optimum overall electric-vehicle design,
2. Assist industry in accelerating advancements in electric-vehicle technologies,
3. Provide analytical and test methodologies and tools for application by industry to electric-vehicle system technology,
4. Identify areas requiring increased R&D attention, and
5. Provide a national data base to enable determination of technology and standards of performance.

Two contracts were placed for integrated test vehicles. Each contract brought together the three different disciplines of vehicle design, electric drive-train design, and electronic control. One major role of this program was the integration of these disciplines into an effective overall electric-vehicle system design.

Vehicles were to include increased range between battery charges (50 percent over existing electric cars), meet existing U.S. safety standards, show contemporary styling, and have generally peppy performance equivalent to that of subcompact cars. The vehicles, ETV-1 and ETV-2, were delivered in 1978 and 1979, respectively. ETV-1 was built by a team consisting of the General Electric Company and the Chrysler Corporation (vehicle) and Glove Union (battery). The Garret/Budd team (ETV-2) included Garret Air Research, the Budd Company (body), Eagle-Picher Industries, Inc. (battery), Dynamic Science Inc. (safety), the Brubaker Group (styling), and All American Racers (supervision and brakes).

Several advances in technology were demonstrated. The aerodynamic design of ETV-1 was tested in the wind tunnel and showed some of the best overall aerodynamic characteristics of cars of its size tested to date (10). Significantly improved battery and electric-system control capability, drive-train performance, load leveling, and integrated structure were also demonstrated. The General Electric/Chrysler entry (Figure 3) was based on the existing Omni-Horizon body design and achieved recognition as a practical design, with potential for the mid-1980s provided battery capability and cost problems could be solved. This car has been extensively tested and is now serving as a test bed for advanced battery concepts. The Garret/Budd entry, which was implemented with 1990 technology, is a hybrid electric with a mechanical flywheel and battery (11). The flywheel, in effect, provides load leveling for the battery, reduces power demands, and thereby increases effective range between charges. During the R&D phase, significant advancements were made both in flywheel design and control and in integrated vehicle structures.

Before the building of ETV-1, the electric car was perceived as a small, golf-cart-type car, too small and too slow for use on the same road with gasoline-powered cars. ETV-1, by using existing technology for the most part, clearly changed that image. Its development showed that it was possible to build an authentic, market-responsive vehicle, provided the battery energy capacity or life (cost) problems or both could be solved. Its speed, handling, and safety tests were proof that a regular car could be propelled with all-electric energy.

It also proved that the engineers from the disciplines of power-train engineering, vehicle technology, and electronics could become an effective team involved in optimizing a design that would have market potential.

ETV-1 and ETV-2 have provided a technology data base that was unavailable by other means. They have indicated the R&D needed at the component and subsystem level for future electric vehicles (12,13). The automobile companies have reviewed the technology used in the model, and the analytical work has been made available for their use.

Except for the battery and control system and for drive-train packaging, the technologies used for improving aerodynamics, reducing rolling resistance, and reducing weight are equally applicable to internal-combustion cars. This means that the drive-train efficiency and cost for future vehicles can be compared on a subsystem basis. (Spinoffs from vehicle R&D are not always as obvious as they are in ETV-1. The perfection of a low-cost, high-powered switching transistor was accomplished and is now used by General Electric in other product lines.)

Motor Trend, a magazine that is often critical of

Figure 3. GE/Chrysler near-term electric vehicle (ETV-1).

government programs, especially those involving automobiles, had this to say about the ETV (Feb. 1980): "This project is one of the best uses of federal tax money in the field of energy, emissions and vehicle design.... The ETV-1 is not only an eye catcher, it is a working mule, and it works well."

VEHICLE RESULTS

The following tentative conclusions regarding integrated-vehicle R&D at the federal level have been developed from this brief examination of three government programs.

Transbus

The real needs of the elderly and the handicapped are better understood because of the Transbus program. The failure of industry to respond to the specification for purchase of 530 buses opened the eyes of many government officials to the real need for better government understanding of the financial risks and planning horizons of major businesses, particularly those in the automotive sector.

Safety Vehicles

Although it is difficult to separate the impacts of the specific parts of the NHTSA program, the ESV has probably done as much for integrating safety concerns for both domestic and foreign producers of automobiles as any of these. The international participation by six countries and the development of elaborate testing facilities in several countries speak to that success. The ESV "weight problem" was a learning experience that caused considerable effort to be spent in system studies before the RSV program was begun. The results of the Calspan/Chrysler effort suggest that some of the RSV safety features have found their way into the Omni/Horizon and probably into other cars as well. The minicar design has demonstrated the possibility of combining a very lightweight with a highly crashworthy structure for the automobile of the future.

Electric Vehicles

The electric-vehicle program did a tremendous amount to alter the image of the electric car from an advanced golf cart to a potentially stylish, peppy electric car that many of us would be willing to own (if the price were right). The program, however, has done little to improve the system infrastructure or to determine the real service and use demand for an electric vehicle.

LESSONS LEARNED

A major reason for this assessment was to develop an understanding of both the good and bad points of those lessons that were learned. Such lessons should be considered in any future vehicle program, as well as in other programs where commercialization and public use are the intended end result.

There is insufficient political staying power (funding) to cover the span of adequate vehicle R&D. Vehicle programs never achieve the preproduction models needed to ensure commercialization. Early prototypes shown to Congress and demonstrated to the consumers and media lead to overselling the readiness of the product. This kind of result further exacerbates the funding problems created by changing priorities or political leadership. Precious R&D money is often the only money quickly available to fund new program initiatives. For example, the omission of preproduction bus manufacture and the service testing of 100 prototype vehicles in the Transbus program reorientation left many unsolved technical problems and was a major reason companies chose not to bid. The RSV program today would be ready to tackle the most important question of very small car safety had it not been recently eliminated because of political initiatives in the safety program.

Good relations and involvement with industry are necessary during the program. No government R&D program for vehicle development can be suitably initiated and carried on without considerable participation by the industry that will eventually put the vehicle or its improvements on the market. All programs suffered from the absence of industry interest or government and industry teamwork pledged to completion. By itself, participation in the program does not commit the corporation to commercialization. Companies have often participated in programs, as appears to be the case with the Transbus and the ESV programs, not because the companies agree with the program or even with its specifications, but because it is a corporate defensive strategy.

To a certain extent, the lightweight RSV was used to prod U.S. automobile manufacturers into looking at new concepts, a fact that annoyed the industry. On the other hand, Calspan's work with Chrysler apparently caused some new safety ideas to be integrated directly into the Omni/Horizon. The data from near-term electric vehicles built by GE/Chrysler and Garret/Budd have been given to industry. Low battery capability and high overall cost are still the major drawbacks to commercialization. However, the program showed that adequate performance could be obtained from existing batteries and improved design of controllers.

Government specifications are often too constraining. Wide-ranging social and political pressures often lead to overspecification, which causes the product to be more expensive and, perhaps, to be engineered in a way less suitable for eventual movement into the marketplace. The rear-barrier crash at 50 mph, side-pole crashworthiness at 30 mph, and rollover at 70 mph contributed significantly to the battle-tank weights of the ESV family sedan. The low-floor, step-design, and axle-weight requirements of the Transbus, because they were too constraining, required a new bus design rather than an evolutionary one.

Planning, including the early establishment of program requirements, is crucial. In evaluating these three programs, it became apparent that the planning and requirements analysis was not always adequate. More preliminary study of alternatives for the elderly and handicapped could have created a different and more evolutionary Transbus program. Realistic safety requirements could have made the ESV more like a 1972 family sedan than tank.

Competition is important. Conversations with participants in all programs revealed that the competitive nature of the program was important. In the electric-vehicle and RSV programs, the chosen contractors (two for each program) explored different technologies; one looked at innovative approaches whereas the other looked at a more evolutionary or nearer-term approach.

International participation is important. The failure to seek international expertise for the Transbus was a negative factor. On the other hand, safety vehicle work has been greatly enriched by extensive foreign interest and heavy participation. The near-term electric vehicle program has enriched U.S. participation in international electric-vehicle conference and technical interchanges.

The government's knowledge of the market and what it takes to stimulate it are lacking. Market studies by government are usually contrary to policy and thus any efforts toward commercialization are seldom handled well. Since the government is often the purchaser of large numbers of vehicles, it could become a catalyst for commercialization in integrated-vehicle programs. Thus it could share the risk and be involved in gathering important data on new-vehicle maintenance, operations, durability, and so forth. Unfortunately, for the three examples here, no such government involvement was devised and/or implemented.

In summary, vehicle R&D programs, although seldom funded adequately enough to achieve commercialization, frequently have value in identifying critical R&D needs in the subsystem or component area. Two of the programs succeeded in showing that technology is available to accomplish some major program goals. It appears clear that public-sector involvement should be stimulatory and at the same time one of partnership with industry. If the desire is to move technology and innovation at the fastest rate in order to achieve national goals, established industry is in a better position to meet such goals and with products that will satisfy the marketplace. The poor but mixed results of our government programs underscore this need.

A strong requirement analysis at the outset and government cooperation with industry as partners are fundamental to future programs. Where international experience and cooperation are available, they should be integrated into the program if for no other reason than to improve cost-effectiveness.

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