PARTNERSHIP FOR A NEW GENERATION OF VEHICLES

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ABSTRACT

On September 29, 1993, President Clinton, Vice President Gore, and the Chief Executive Officers of Chrysler, Ford, and General Motors announced the formation of a historic, new partnership aimed at strengthening U.S. competitiveness while protecting the environment by developing technologies for a new generation of vehicles. Tabbed the "Partnership for a New Generation of Vehicles" (PNGV), the program's long-term objectives include developing a range of technologies to yield automobiles with a threefold improvement in fuel efficiency and reduced emissions. This is to be achieved without compromising other features such as performance, safety, and utility. This also requires developing and introducing manufacturing technologies and practices that will reduce the time and cost associated with designing and mass producing this new vehicle *(1)*. Within the Department of Transportation, NHTSA is the focal point for the PNGV program support. Toward this support, the agency's role is to ensure that the PNGV developed vehicles will meet existing and anticipated safety standards and that the overall crash and other safety attributes are not compromised by their light weight and the use of new advanced materials used in production of the vehicles. This paper is written to provide a general overview of the PNGV program and to outline the activities that NHTSA has planned in support of its role in the program.

INTRODUCTION

On September 29, 1993, President Clinton, Vice President Gore, and the Chief Executive Officers of Chrysler, Ford, and General Motors announced the formation of a historic, new partnership aimed at strengthening U.S. competitiveness while protecting the environment by developing technologies for a new generation of vehicles. Tabbed the "Partnership for a New Generation of Vehicles" (PNGV), the program's long-term objectives include developing a range of technologies to yield automobiles with a threefold improvement in fuel efficiency and reduced emissions. This is to be achieved without compromising other features such as performance, safety, and utility. This also requires developing and introducing manufacturing technologies and practices that will reduce the time and cost associated with designing and mass producing this new vehicle.

To address the aforementioned objectives, the Federal Government and the United States Council for Automotive Research (USCAR), which represents Chrysler, Ford, and General Motors, have initiated activities to address the following three interrelated goals:

- Goal 1: Significantly improve national competitiveness in manufacturing.
- Goal 2: Implement commercially viable innovation from ongoing research on conventional vehicles.
- Goal 3: Develop a vehicle to achieve up to three times the fuel efficiency of today's comparable vehicle (i.e., the 1994 Chrysler Concorde, Ford Taurus, and Chevrolet Lumina).

Goal 1

The goal is to improve productivity of the U.S. manufacturing base by significantly upgrading U.S. manufacturing technology, including the adoption of agile and flexible manufacturing and including the reduction of cost and lead times while reducing the environmental impact and/or improving quality.

Manufacturing technologies are critically important to assuring competitiveness in today's market place, as well as assuring the ability to produce the new generation of vehicles. The focal areas of research and development for achieving Goal 1 include improving the design and development processes to reduce lead times and achieve cost reductions; developing new manufacturing and vehicle assembly systems that will increase productivity; and assuring the ability to integrate and validate combined technologies.

Research and development may include the following specific technologies: flexible/agile tooling and equipment that will reduce costs and model change-over time; more sophisticated computer simulation systems for testing complex research designs as they apply to issues such as tire rolling resistance, braking characteristics, etc; design and analytical methods to determine strength characteristics of composite structures; and others.

Development and deployment of these new technologies will increase the competitiveness of U.S. manufacturing industries in general, and will strengthen the U.S. automobile industry in particular. Research also is required to assure the manufacturability of the advanced technologies necessary to address Goal 3.

Goal 2

The goal is to pursue advances in vehicles that can lead to improvements in the fuel efficiency and emissions of standard vehicle designs, while maintaining safety performance. Research will focus on technologies that reduce the demand for energy from the engine and drive train. Throughout the research program, the industry commits to apply those commercially viable technologies resulting from this research that would be expected to increase significantly vehicle fuel efficiency and improve emissions.

In order to maximize fuel efficiency and minimize emissions, the combustion process must be analyzed with sufficient accuracy so as to predict energy release and pollutant formation. Furthermore, improved diagnostics are required to assure that the desired processes are actually occurring during operation. Other key factors toward addressing Goal 2 include the design and fabrication of components that can operate in increasingly more severe operating environments than with current engines (e.g., higher temperatures, higher cylinder pressures, higher loads and stresses, lower oil viscosity, and more chemically reactive fuels). Engines running at higher temperatures and pressures will result in increased wear on piston rings, cylinder liners, valves, valve stems, fuel injectors, cams, bearings, and other components. Therefore, improved methods for analyzing friction, wear, and lubrication in materials, components, and engine systems are needed.

Research is also needed on vehicle technologies that reduce the demand for energy from the engine and drive train. Toward this need, work is needed on improved aerodynamics and reduced rolling resistance. Such research contributes to Goal 2 in the near term and to Goal 3 in the longer term.

Goal 3

The goal is to achieve fuel efficiency improvement of up to three times the average Concorde/Taurus/Lumina with equivalent customer purchase price of today's comparable sedans, adjusted for economics. This is to be achieved while costing no more to own and drive than today's automobiles (adjusted for economics) and while meeting customers' needs for quality, performance, and utility.

In developing a vehicle which achieves up to three times the fuel efficiency of today's comparable vehicles, the PNGV partners have determined a number of specific assumptions/requirements toward this venture. The first is an assumption regarding the use of an efficiency metric of miles per equivalent gallon of gasoline. If an alternative source of energy is used, the goal will be miles per BTU equivalent of a gallon of gasoline (or 114,132 BTUs). The second is a requirement that the vehicles will be designed to Tier II emissions at the default levels of 0.125 HC, 1.7 CO, and 0.2 Nox at 100,000 miles while complying with other Clean Air Act requirements. The third is a requirement that the vehicles meet present and future Federal motor vehicle safety standards, while also meeting equivalent in-use safety performance. The fourth is a requirement that recyclability be achieved for at least 80 percent of the vehicle materials, up from the seventy-five percent industry average today. The final requirement is that the vehicle concept be available in six years and a Production Prototype be available in approximately ten years.

The PNGV partners also have defined what is meant by a comparable family design vehicle. First, the function of the vehicle is to carry up to six passengers with a comfort level equivalent to the Chrysler Concorde, the Ford Taurus, and the Chevrolet Lumina cars with the fuel efficiency of up to three times the average 1994 Concorde/Taurus/Lumina 26.6 mpg (unadjusted combined metro highway based on Federal Test Procedure), or 26.6 miles per 114,132 BTUS. (Three times this efficiency is 80 miles per 114,132 BTUs.) Secondly, the vehicle must have an acceleration of 0-100 kmph (0-60 mph) in 12 seconds at its curb weight with 300 lbs of passenger and a full fuel tank. Thirdly, the luggage capacity must be at least 475 liters (16.8 cubic feet) and its load carrying capacity must be equivalent with the Concorde/Taurus/Lumina (six passengers, full fuel tank, and 200 lbs of luggage). The fourth is that the vehicle must have an operating metro-highway range of 610 kilometers (380 miles) on the 1994 Federal Drive Cycle. The fifth is that the vehicle provides the equivalent performance in all aspects including acceleration, cruising speeds, gradeability, and driveability at sea level and at altitude; provide equivalent performance in ride, handling, an noise, vibration, and harshness control; provide the customer certain features and options including climate control and entertainment packages; and provide an equivalent total cost of ownership (adjusted for economics). The sixth is that the vehicle have a useful life of 160,000 km (100,000 miles) at a minimum, and comparable if not improved service intervals and refueling times. Finally, the vehicle is to be easily homologated for export and sale in major world markets.

Major advances must be made in several technologies on order to achieve an 80 mpg vehicle. A three pronged approach is required to shift the energy balance in favor of improved fuel economy. These include converting energy more efficiently, implementing regenerative braking to recapture energy, and reducing the energy demand for the vehicle. An examination of the design space for these approaches identifies three technical targets to improve the fuel efficiency: improve the fuel efficiency of the primary fuel converter, reduce the mass of the vehicle, and implement efficient regenerative braking.

The design space has both theoretical and practical limits. On the basis of practically achievable thermal efficiencies with various heat engines, three times the fuel economy may not be reached by engine improvements alone. The thermal efficiency needed ranges from 40 to 55 percent, which is about twice that of today's engines. Even with advanced fuel cells, which do have the higher potential efficiencies than the heat engines, other vehicle improvements are likely to be needed.

Analyses show that an efficient regenerative braking system must be implemented to recover energy store or reuse energy currently lost when using brakes, even with improved engines and lighter vehicles. This reduces the amount of energy which must be converted from fuel, normally the most inefficient step of the energy cycle.

Also, even with improved power converters and regenerative braking, reductions in vehicle mass on the order of 20 to 40 percent from today's baseline vehicles are required. These levels of mass reduction are beyond the simple refinement of today's steel frame, steel body construction, and will involve the introduction of entirely new classes of structural materials to the automobile.

Finally, several other advances must be made, though these contribute less to the overall system goal. These advances include reduced aerodynamic drag, reduced tire rolling resistance, and more efficient mechanical and electrical components.

In summary, in order to reach Goal 3, research and development is needed in the technology areas leading to vehicle and propulsion system improvements. These technologies include advanced lightweight materials and structures, energy efficient conversion systems (e.g., advanced internal combustion engines and fuel cells), energy storage devices (e.g., advanced batteries, flywheels, and ultracapacitors), more efficient electrical systems, and waste heat recovery.

NHTSA INVOLVEMENT

Within the Department of Transportation, NHTSA is focal point for the PNGV program support. Toward this, the agency's role is to ensure that the PNGV developed vehicles will meet existing and anticipated safety standards and that the overall crash and other safety attributes are not compromised by their light weight and the use of new advanced materials used in production of the vehicles.

The most recent projections indicate that a 40 percent reduction of the vehicle mass will be required to meet the fuel economy requirements of the PNGV program. This reduction, coupled with the potential use of materials other than the conventional steels used in automobile construction today and with the possible use of entirely unique power trains, requires that careful attention be given in determining the overall crash safety of the vehicles. Beyond the testing required by the Federal motor vehicle safety standards, the safety analysis must include evaluating the performance of the vehicles in crash modes that are representative of the real world accident environment. When considering the PNGV vehicles interactions with the existing fleet, the mass reduction requires extra attention be given to crash energy absorption characteristics of the vehicle structure and to the performance of the occupant restraint systems. Furthermore, the potential of developing vehicles with mass distributions that vary significantly from today's vehicles may require careful scrutiny regarding how these vehicles will behave in their interactions with roadside safety hardware such as guard rails, breakaway luminaire supports, etc.

Toward meeting the aforementioned stated objectives, research will be initiated to develop advanced computer models and acquire the computing capacity necessary to evaluate the crashworthiness characteristics of alternate vehicle designs and of the new lightweight materials. Detailed finite element models will be developed for each of the PNGV baseline vehicles and for vehicles representing the fleet (e.g., subcompact, compact, mid-sized, and full-sized cars, small and large pickup trucks, and a minivan). This activity involves the tear down of the PNGV baseline vehicles and selected fleet vehicles for scanning the vehicles to develop geometric data to be used in prescribing the finite element mesh, and for measuring the inertial and other physical properties of the vehicles. Crash testing will be conducted to validate the models as well as provide for audits of simulations undertaken in support of the fleet analysis. Design concepts will be explored and evaluated for the various power trains under consideration for the PNGV vehicles. This includes exploring the use of advanced structural materials such as composites and aluminum. It is anticipated that research into improved material models will be required in the computer software to accommodate these studies. Finally, a system model will be developed for identifying optimal characteristics for the PNGV vehicles.

The approach to be used in the system model will be similar to that found in Reference 2. In particular, the approach to crashworthiness optimization may be stated formally as the following non-linear problem:

$$\text{Minimize Inj}\ (\underline{x},u) = \sum p_i\, s_i\, (\underline{x},u) \qquad [1]$$

subject to

$$Wgt\ (x) \leq Wgt_{max}$$
$$Cost\ (\ x,\ w(x)\ ) \leq Cost_{max}$$
$$x_{min} \leq x \leq x_{max}$$

where

x	— Vector of Design Variables
u	— Belt Usage Rate
Inj (x,u)	— Total Injuries
Wgt(x)	— Incremental weight associated with design 'x'
Cost	— Incremental cost associated with x and Wgt(x)
Wgt_{max}	— Upper Constraint on incremental weight
$Cost_{max}$	— Upper Constraint on incremental cost
p_i	— Probability of Event i
s_i	— Injuries resulting from occurrence of Event i

The objective expressed in Equation 1 is to determine that vector of design variables which minimizes total injuries or some measure of societal cost of total injuries *(3)*. The simulations will attempt to minimize normalized harm, defined as total harm in dollars normalized by the harm associated with an AIS 6 injury level. Total harm is computed by summing the harm incurred in each of accident encounters i weighted by p_i, the annual expected probability of event i.

The incremental weight penalty associated with any proposed design modifications w(x) is limited to the upper constraint Wgt_{max}. Similarly, the incremental cost of the proposed design modifications is limited to an upper constraint of $Cost_{max}$. The incremental cost in this context includes both the additional cost of design modifications and an estimate of the cost of material substitution to reduce weight. To ensure that design modifications lie within realistic ranges, the design variable vector is constrained by lower and upper limits on each design modification. The annual expected probability of a crash event i, sometimes referred to in the literature as exposure, is computed based on historical accident data. For the model, a crash event i is completely characterized by prescribing the crash speed, the impacting vehicle weight, the occupant seating location, the occupant height, the occupant gender, and the occupant restraint type.

NHTSA also will provide for peer reviews of the conceptual designs developed by the PNGV program, and will initiate the creation of a comprehensive knowledge base for conducting analyses of the impact of the new vehicles on the U.S. economy, transportation system, and motor vehicle industry. For the various propulsion and vehicle design options, the need for new materials and components will be evaluated. On the basis of these needs, the resulting impacts will be assessed. These will include the cost and availability of materials (including the need for imports), manufacturing capacity, new facilities and tooling, capital requirements, impact on service and repair industries, impact on labor, impact on the fuels industry (including capital, distribution, and environmental concerns), and balance of trade considerations.

ACKNOWLEDGMENT

The information presented for the general overview of the PNGV program was extracted directly or paraphrased from that provided by the United States Department of Commerce's "Partnership for a New Generation of Vehicles Program Plan" (Reference 1).

REFERENCES

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