HSWR-001

Research and Development Plan for

High-Strength/Weight Reduction Materials

September 2002

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RESEARCH AND DEVELOPMENT PLAN FOR HIGH-STRENGTH/WEIGHT REDUCTION MATERIALS

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EXECUTIVE SUMMARY

Recognizing the importance of heavy vehicles to the health of the national economy, the Department of Energy (DOE) created the Office of Heavy Vehicle Technologies (OHVT) in 1996 with a mission to conduct, in collaboration with its industry partners and their suppliers, a customer-relevant national program to research and develop technologies that will enable trucks and other heavy vehicles to be more energy-efficient and to use alternative fuels while reducing emissions. As one part of the strategy, the High-Strength Weight Reduction (HS/WR) Materials Program was formed to identify lightweighting materials and materials processing technologies that can contribute cost-effectively to reducing parasitic energy losses due to the weight of the vehicle without sacrificing strength and functionality. A workshop to develop a Multiyear Program Plan for the HS/WR Materials Program was held at the National Transportation Research Center in Knoxville, Tennessee, on April 24–25, 2002. A total of 50 attendees participated who represent various segments of the heavy vehicle industry, including original equipment manufacturers (OEMs), first-tier suppliers, and materials suppliers, as well as academia, national laboratories, and DOE. The meeting included introductory presentations by leading members of the industry discussing needs for the three major vehicle subsystems: body and cab structures, chassis structures, and drivetrain and suspension structures. Presentations were followed by break-out sessions examining needs in the areas of materials development; manufacturability; and maintenance, repair, and recycle.

The purpose of the Research and Development (R&D) Plan is to identify major technology barriers that inhibit the introduction of lightweighting materials, establish priorities and approaches for addressing these barriers, and set targets for funding levels to accomplish the established goals. The workshop and the R&D Plan that results provide an opportunity for various segments of the heavy vehicle industry to share their ideas and help formulate an aggressive national research agenda.

The workshop participants agreed that various types of lightweight materials or materials that enable lightweighting of vehicles are needed to meet the weight-reduction goals of various trucking industry groups and DOE. The materials selected for development in the program should be chosen by means of technology pull—that is, by the needs and requirements of the industry to meet the technical and programmatic goals. Relevant materials include light metals, including aluminum, magnesium, and titanium; advanced engineered materials, such as metal matrix composites (MMCs) and ultralight materials (e.g., engineered laminate materials and foams); materials that enable lightweighting, such as advanced high-strength steels or stainless steels; reinforced polymer composites (reinforced with glass fiber, carbon fiber, combinations of glass and carbon fiber, other advanced fibers, and nano-particulates); and unreinforced polymers. These materials must be strategically applied to optimally match their special properties to key application needs. This approach will allow reduced weight at minimal or no cost penalty while still addressing the optimization of strength and stiffness; improvement of vehicle dynamics, handling, and safety; and improvement of durability and maintenance. In addition to choosing the right materials, it will be necessary to choose robust, flexible, and reliable manufacturing processes to optimize for part consolidation, net-shape forming, reduced assembly costs, and low-cost tooling. Finally, the total life-cycle costs to the trucking industry demand that maintenance, repair, and recyclability be addressed.

Although the groups in the various breakout sessions identified many barriers to the widespread introduction of lightweight materials in the heavy vehicle industry, most of the barriers can be grouped into one of a few major categories:

1. Cost: In particular, the current cost of lightweighting materials impedes their widespread use in heavy-vehicle structural applications.
2. Design and simulation technologies: Design data, test methodologies, analytical simulation tools, design flexibility, and durability data are inadequate for many lightweight materials.
3. Manufacturability: Methods for the cost-competitive production of components for heavy vehicles are not sufficiently well developed.
4. Tooling and prototyping: The cost and fabrication time of tooling for forming components made with lightweight materials is too high for volumes typical for the heavy-vehicle industry.
5. Joining and assembly: High-yield, robust joining technologies for lightweight materials and for joining dissimilar materials and hybrid structures are inadequate or lacking.
6. Maintenance and repair: Technologies for cost-effective maintenance and repair are inadequate for most lightweight materials.

Summary of R&D Needs—Body and Cab Structures

Cab structures represent a key materials and manufacturing challenge for heavy-vehicle manufacturers. Development of body structure design; selection of materials and corresponding manufacturing processes; assembly; and in-service performance, durability and maintenance are the direct responsibility of the truck OEMs. Body structures and associated styling are considered a differentiating aspect of the manufacturer's vehicle and are therefore of great importance to heavy truck OEMs. Achieving a goal of 20% reduction in body structure weight is technically feasible for medium- and heavy-duty vehicles. However, weight reductions must be accomplished with minimal cost, durability, and maintenance penalties. The use of new materials and cost-effective manufacturing technologies will be an important contributor to implementing lighter-weight, more efficient and cost-effective body materials and designs.

Key R&D needs in body and cab structure include

- Lower material cost
- User-friendly databases with uniform architecture for all materials that can enable both design and simulation of materials behavior during the manufacturing process and for the final product
- Design data and methodologies for "hybrid material structures" that take advantage of inherent characteristics of the materials and optimize for weight, performance, and cost
- New alloys with improved, uniform, and consistent properties (stiffness, strength, fatigue resistance, formability)
- Standardized materials specifications and product forms (especially for polymer composites) that are suited to heavy-vehicle manufacturing and performance needs
- Polymer materials with increased ultraviolet resistance and tolerance for weather- and impact-induced damage to simplify, reduce, or eliminate painting in vehicle production and field repair processes

- Enhanced durability for all materials to reflect the duty cycles of heavy vehicles
- Low-cost corrosion-resistant materials and coatings
- Advanced stamping, forming and joining technologies for metallic components that maximize component function, reduce part count and assembly cost, and reduce weight while utilizing significantly cheaper and more flexible tooling approaches
- Modeling and simulation tools that assist in efficient design of body structures, eliminate time-consuming prototype development, and predict properties and in-service performance of manufactured structures, including high-rate deformation for crashworthiness design
- New, innovative manufacturing, joining, and assembly technologies for carbon-fiber composites and hybrid material structures, including the capability to produce Class A surfaces
- New manufacturing technologies and their associated material systems that provide product design flexibility, improved durability, and corrosion resistance in real-life truck applications and are maintainable and recyclable over the life of the vehicle
- Accelerated testing methods to simulate materials and structural performance in operating environments
- Repair procedures for new lightweight materials
- Cost-effective disassembly for maintenance, repair, and recycling

Summary of R&D Needs—Chassis Structures

Chassis structures, taken to include the vehicle frame systems, the fuel system, battery boxes, and other chassis-attached accessories, represent approximately 15% of the overall tractor weight. They are characterized as large, built-up structures that must serve multiple vehicle functions; are highly loaded; and must operate under extreme durability, fatigue and corrosion conditions. With few exceptions, medium- and heavy-duty frame structures are built around a pair of "C"-channel steel rails, with multiple bolted or riveted crossmembers along the length of the frame. As a result, the frame rail and crossmembers represent the largest opportunity for significant weight reductions in the frame structure. Many technologies developed for the tractor frame could also be applied to lightweight trailer designs. Despite the weight reduction potential, the requirement for low-cost manufacturing flexibility (customization), the customer requirements for vehicle configuration, and the need for improved durability and lower maintenance make the application of lighter-weight materials and designs a challenging manufacturing R&D area. From the truck design perspective, the vertical and lateral bending stiffness of the frame structure must be maintained at the current levels or in some instances even increased. This requirement is necessary to preserve or improve the ride and handling and braking dynamics performance, and it presents significant challenges from the design and materials engineering perspectives in designing for minimum weight.

Key areas for R&D in chassis structures include

- Improved databases and design guidelines for all materials that allow optimization of structures for weight, cost, and performance
- Improved alloys with fatigue resistance, durability, and strength

- Advanced casting technologies for light metals and high-strength steels that result in thinner, lighter castings with improved fatigue and corrosion resistance
- Corrosion-resistant materials, advanced coatings, and other corrosion protection methods to mitigate the effects of corrosion induced by ice-clearing chemicals used on roadways
- Better materials constitutive and processing models for reinforced polymer composites
- Advanced frame rail and crossmember manufacturing technologies for all materials that can significantly reduce frame weight while meeting and improving vehicle performance, durability, maintenance requirements, and design flexibility
- Joining methods for lightweight metal and polymer composite frame designs that maintain the required manufacturing flexibility while improving joint efficiency; reducing material property degradation; and significantly improving the fatigue, fretting, and corrosion performance of the frame structure to allow designers the flexibility to use these materials in structural applications
- Design and manufacturing processes for advanced lightweight materials, especially hybrid materials systems, and advanced joining methods that have the potential to reduce frame weight and facilitate the use of alternative frame materials
- Improved, cost-effective methods for isolation and/or protection to avoid galvanic corrosion
- Repair procedures, including field repair, for light metals, polymer composites, high-strength steels, advanced materials such as MMCs, and hybrid materials systems
- Improved methods of detecting and monitoring corrosion
- Preventative maintenance methodologies

Summary of R&D Needs—Suspension and Drivetrains

Suspension and drivetrain components represent a good candidate for weight reduction through the application of high-strength, lightweight materials. However, because of the high power-transmission loads and reliability requirements, many key components are likely to continue to be manufactured from iron-based materials. They include gear sets, pinions, bearings, and high-strength bolts. The combinations of dissimilar material systems that are found in most drivetrain and suspension systems—combined with their exposure to wet, corrosive, and abrasive road conditions—present significant corrosion challenges. From the owner/operator perspective, a top R&D priority for suspension and drivetrain materials and manufacturing would be to improve the corrosion resistance of components, improve joining methods, and prevent dissimilar material reactions in corrosive environments. Manufacturing methods for high-temperature, wear-resistant brake materials represent a good R&D opportunity, and advances in this area will provide weight savings as well as improvements in vehicle safety.

General R&D needs for suspension and drivetrain materials include

- Alloys with better wear resistance, higher strength and stiffness, and improved durability
- Improved protective coatings and surface modification or materials with improved corrosion characteristics, and methods to prevent galvanic corrosion between dissimilar materials in suspension/drivetrain systems

- Improved casting technologies that provide flexibility in controlling and varying the wall thickness of large drivetrain and suspension castings to provide the opportunity for reduced weight and improved performance
- Improved manufacturing technologies for advanced cermets and carbon-carbon brake friction materials that provide dual benefits of reduced weight (sprung weight) and improved vehicle safety
- Enhanced ability to design and fabricate hybrid material structures
- Lower-cost net-shape manufacturing technologies for composites with improved resistance to abrasion and environmental degradation for use in highly stressed components
- Joining technologies for similar and dissimilar materials to enable the introduction of hybrid material structures
- Inexpensive, field-deployable systems that allow early detection of degradation and preventive maintenance

This R&D Plan for HS/WR Materials includes a detailed plan for materials R&D to support the technologies described. Finally, an estimate of the funding required to complete the identified research and development is presented. Funding requirements are summarized in the following table.

High-Strength/Weight Reduction Materials Program funding requirements by fiscal year

Technology	**Fiscal year ($ in thousands)**						
	2003	**2004**	**2005**	**2006**	**2007**	**2008**	**Total**
Materials development	6,500	10,000	10,000	10,000	8,500	6,000	51,000
Manufacturing	10,500	12,000	15,000	16,000	13,000	10,000	76,500
Maintenance, repair, recycling	1,000	2,000	3,000	4,000	2,500	2,000	14,500
Total	**18,000**	**24,000**	**28,000**	**30,000**	**24,000**	**18,000**	**142,000**

INTRODUCTION

Recognizing the importance of heavy vehicles to the national economic health, the Department of Energy (DOE) created the Office of Heavy Vehicle Technologies (OHVT) in 1996. Its mission is to conduct, in collaboration with its industry partners and their suppliers, a customer-relevant national program to research and develop technologies that will enable trucks and other heavy vehicles to be more energy-efficient and to use alternative fuels while reducing emissions. As one part of the strategy, the High-Strength Weight Reduction (HS/WR) Materials Program was formed to identify lightweighting materials and materials processing technologies that can contribute cost-effectively to reducing parasitic energy losses due to the weight of the vehicle without sacrificing strength and functionality. A workshop to develop a Multiyear Program Plan for the HS/WR Materials Program was held at the National Transportation Research Center in Knoxville, Tennessee, on April 24–25, 2002. A total of 50 attendees participated who represent various segments of the heavy vehicle industry, including original equipment manufacturers (OEMs), first-tier suppliers, and materials suppliers, as well as representatives from academia, the national laboratories, and DOE. The meeting included introductory presentations by industry leaders discussing needs for the three major vehicle subsystems: body and cab structures; chassis structures; and drivetrain and suspension structures. Presentations were followed by break-out sessions examining needs in the areas of materials development, manufacturability, and maintenance, repair, and recyclability.

The purpose of the plan is to identify major technology barriers that inhibit the introduction of lightweighting materials, establish priorities and approaches for addressing these barriers, and set targets for funding levels to accomplish the established goals. The workshop and the research and development (R&D) plan that resulted provide an opportunity for various segments of the heavy-vehicle industry to share their ideas and help formulate an aggressive national research agenda.

Program Goals

In support of DOE's overall goal to enable trucks and other heavy vehicles to be more energy-efficient and to use alternative fuels while reducing emissions,[1] the HS/WR Materials Program seeks to reduce parasitic energy losses due to the weight of heavy vehicles without reducing vehicle functionality, durability, reliability, or safety, and to do so cost-effectively. In addition, it is recognized that improved materials may enable implementation of other technologies that can further improve the fuel efficiency of the vehicles. The Program has a more specific goal of a 15–20% weight reduction for Class 8 tractor-trailer combinations. This is consistent with the 5,000-lb reduction established as a goal by the American Trucking Association.[2] Recently, the 21st Century Truck Partnership developed an R&D Plan for Materials that has adopted many of the same targets.[3] Goals for other classes of heavy vehicles vary between a 10 and 33% reduction

[1] *OHVT Technology Roadmap*, DOE/OSTI-11690R1, February 2000.
[2] Private communication, American Trucking Association.
[3] *21st Century Truck Partnership R&D Plan for Materials*, 21CT-002, December 12, 2001.

in vehicle weight, depending on performance requirements and duty cycles. Weight reduction must not in any way sacrifice the durability, reliability, and performance of the vehicle. Attaining these goals by reducing inertial loading will yield substantial benefits: increased fuel efficiency with concomitant reductions in emissions, increased available payload capacity for some vehicles, reduced rolling resistance, and optimized safety structures and aerodynamic drag reduction systems.

Materials Requirements

The workshop participants agreed that various types of lightweight materials, or materials that enable lightweighting of vehicles, are needed to meet the weight reduction goals of various trucking industry groups and DOE. The materials chosen for development in the program should be chosen by means of technology pull—that is, by the needs and requirements of the industry to meet the technical and programmatic goals. Relevant materials include light metals, including aluminum, magnesium, and titanium; advanced engineered materials, such as metal matrix composites (MMCs) and ultralight materials (e.g., engineered laminate materials and foams); materials that enable lightweighting, such as advanced high-strength steels or stainless steels; reinforced polymer composites (reinforced with glass fiber, carbon fiber, combinations of glass and carbon fiber, other advanced fibers, and nano-particulates); and unreinforced polymers. These materials must be strategically applied to optimally match their special properties to key application needs. This approach will allow reduced weight at minimal or no cost penalty while still addressing the optimization of strength and stiffness; improvement of vehicle dynamics, handling, and safety; and improvement of durability and maintenance. In addition to choosing the right materials, it will be necessary to choose robust, flexible, and reliable manufacturing processes to optimize for part consolidation, net-shape forming, reduced assembly costs, and low-cost tooling. Finally, the total life cycle costs to the trucking industry demand that maintenance, repair, and recyclability be addressed.

Barriers

Although the groups in the various breakout sessions identified many barriers to the widespread introduction of lightweight materials in the heavy vehicle industry, most of the barriers can be grouped into one of the following major categories.

A. **Cost.** The current cost of lightweighting materials (compared with plain carbon steel and cast iron) impedes their widespread use in heavy-vehicle structural applications. In particular, the cost of primary aluminum, magnesium, and titanium is too high. Carbon-fiber-reinforced composites (both carbon fiber and resins) and other advanced materials, such as MMCs, also suffer from the high cost of starting materials. Most manufacturing processes for lightweight materials are more expensive than processes used for current materials.

B. **Design and simulation technologies.** Adequate design data (e.g., materials property databases), test methodologies, analytical simulation tools, and durability data do not exist for many lightweight materials. Current manufacturing processes for lightweight materials lack design flexibility and do not optimize the use of the

materials for body structures. Process modeling tools for lightweight materials are inadequate, especially for processes required for manufacturing polymer composites. Simulation tools to predict the structural performance of components made of lightweight materials are lacking.

C. **Manufacturability.** Methods for the cost-competitive production of components for heavy vehicles are not sufficiently well developed. Composite processing and metal forming technologies that yield the required component shape and properties in a cost-effective and environmentally conscious manner need to be developed or improved. They also must be made compatible with heavy-vehicle manufacturing procedures and volumes.

D. **Tooling and prototyping.** The cost of tooling for forming components made with lightweight materials is too high for the volumes typical for the heavy-vehicle industry. The development and fabrication time required for prototyping components is too high.

E. **Joining and assembly.** High-yield, robust joining technologies for lightweight materials are not sufficiently developed. Assembly and joining techniques for dissimilar materials and hybrid structures are inadequate.

F. **Maintenance, repair, and recycling.** Technologies for cost-effective maintenance and repair are inadequate for many lightweight materials. Recycling methods for lightweight materials are not as well developed as those for ferrous materials. Infrastructure and markets for efficient use of recycled composites are inadequate. Damage resistance and tolerance are not well developed for many lightweight materials.

The remainder of this document will present the technical approach suggested for overcoming these barriers for each of the three vehicle subsystems. Although the workshop was of necessity divided into segments focused on the three subsystems, it is clear that there is considerable overlap in the materials, manufacturing, and performance requirements of these systems. For example, needs, technical barriers, and technologies with potential to overcome the barriers to the introduction of lightweight materials for chassis applications are similar to those for suspension applications. In order to capture as accurately as possible the priorities transmitted by the participants and preserve the general sense of that input, some amount of duplication will be maintained. Similarly, there is unavoidable overlap between materials development and manufacturing. For instance, the development of alloys that are more weldable might be considered a material development need, while improved joining technology may be considered a manufacturing issue. Likewise, significant R&D (and possible materials development) is needed to gain an understanding of the effect of holes on the behavior of carbon-fiber-reinforced composites, while joining methods that allow frames to be customized and reconfigured are essential to lower-cost manufacturability. No attempt was made to remove these overlaps, since repetition serves to reinforce the need to overcome these major barriers.

BODY AND CAB STRUCTURES

Background

For medium and heavy truck body structures, the types of materials that are used, the manufacturing technologies that are available, and the performance requirements of the structure in commercial service are interrelated and strongly influence the final weight of the body structure. Until recently, carbon steel was the material of choice for body and closure panels for most medium-duty vehicles (Class 3–6) and heavy trucks (Class 7 and 8), as well as all classes of highway vehicles, including automobiles; there was also some usage of high-strength steels. This situation was due mainly to the mature state of the steel industry in meeting the demands of the transportation industry. In particular, the cost of steel is low, the manufacturing infrastructure is well established, and the properties of steel have traditionally met all of the performance requirements. In general, cost is the largest obstacle to the incorporation of advanced lightweight materials into heavy-vehicle structural applications. However, other barriers to the increased use of these materials also remain.

Manufacturing techniques that are used for these vehicles are strongly influenced by production volumes and customer needs. For medium-duty trucks that have production volumes in the high tens-of-thousands range, the cab body is most often manufactured from high-volume steel stampings, spot-welded, and assembled using highly automated production lines and tooling. In this case, cab body structures are often derived from those of high-volume light-duty pick-up trucks and vans, or are specifically designed as bodies for medium-volume vehicles. For the higher-volume medium-duty market, vehicle cost is typically the top customer priority. In contrast, many Class 8 cab bodies are produced in volumes ranging from several thousand to up to 50,000 units per year. However, within this wide range of production volume, there is a high degree of customization and a large number of unique vehicle configurations that tend to preclude heavy investment in tooling and highly automated assembly. Although many new Class 7–8 cabs are actually of aluminum and/or reinforced polymer construction, the need for higher-strength alloys; improved, cost-effective manufacturing technologies; innovative designs; and lower-cost new materials remains.

The requirements for trailers for Class 7–8 vehicles vary tremendously depending on duty cycle. Some manufacturers may produce 50–60 different models in response to customer demands. In weight-sensitive applications, it may be desirable to reduce trailer weight by up to 1000 lb. A typical enclosed van trailer design consists of a box with aluminum or steel I-beam cross-members, an aluminum/wood (oak plank) floor, aluminum or steel/fiberglass hybrid side panels, and steel frame rails. Refrigerated trailers normally use aluminum flooring with insulation below. Trailers for hauling bulk commodities have a completely different set of performance requirements and consequently are constructed of different specialty materials.

Vehicle weight can be an important factor to many Class 8 fleets and operators, and therefore lightweight materials and manufacturing technologies for lightweight/high-

strength materials are more of a priority to the customer. However, reduced vehicle weight cannot be considered without also considering the effects of these new materials on maintenance, repair, and recycling. Low industry profit margins compel the use of relatively inexpensive materials and rapid, inexpensive, robust maintenance and repair methods that can be accomplished by semi-skilled repair technicians. Furthermore, low profit margins for manufacturers discourage innovation, even in the area of maintainability. Maintenance and repair issues are also affected by varying incentives for fleets versus individual owners and for owners versus operators. At present, U.S. market incentives do not favor vehicle recycling. However, increased competitive pressures in a worldwide market are placing new demands on vehicle manufacturers and fleet operators. Additional demands will come from the increased emphasis worldwide on recyclability and environmentally benign manufacturing.

Goals

The general goals for medium- and heavy-duty truck body structures are to reduce the overall weight of the vehicle by at least 20% while maintaining the performance, safety, and durability of the vehicle. Because of the price sensitivity of medium- and heavy-duty vehicles, weight reduction must be accomplished with minimal negative impact on the total vehicle cost. To accomplish this goal, lightweight materials, or materials that enable the lightweighting of the vehicle, must be identified and/or developed with specific applications in mind. Appropriate information must also be developed to enable design engineers to take advantage of the lightweighting potential. In addition, advanced manufacturing technologies are needed that facilitate the use of these materials; and the structural designs developed must reduce tooling cost, consolidate parts, and reduce assembly cost. Of course, the performance of the structures must meet or exceed that of structures made of the materials currently used in terms of safety, durability, and structural dynamics behavior.

Technical Approach

Materials Development

Discussions that focused on the materials development technology areas important to the introduction of lower-mass materials into body structures of heavy vehicles identified a number of needs common to more than one material.

Cost. The number one need for all lightweight materials is lower cost for primary materials. However, in many cases—such as the extraction of aluminum, magnesium, and titanium from ore—the technology development needed is beyond the scope of the HS/WR Materials Program. In some cases, it is being addressed elsewhere. Nonetheless, the feasibility of novel technologies with potential to address this basic need should be explored when appropriate. Research aimed at reducing the cost of carbon fiber and resin systems for reinforced polymer composites, and of reinforcements for MMCs, will be pursued where it is clear that gaps in technology exist.

Design/modeling. It is also clear that better databases must be developed for all lightweight materials. These databases must be user-friendly, with improved ease of use for both design and simulation, and must reflect accurately the performance needs of heavy vehicles, including durability. Along with the basic properties, constitutive models must be developed for these materials. Materials-specific design methodologies are needed for both advanced metals and composites. These methodologies must take advantage of the inherent characteristics of the various materials and allow designs to be optimized for weight, performance, safety, and cost. Development of both system-level and component- level design and manufacturing modeling tools is needed to enable industry to realize the advantages provided by lightweight materials.

Hybrid structures. R&D is needed to provide heavy-vehicle manufacturers with the design data and methodologies necessary to design "hybrid materials structures." These structures, designed to take advantage of the inherent properties of a combination of lightweight materials, will allow manufacturers to optimize weight and performance by using expensive materials only locally where they are required. Multi-material computer-aided engineering tools are needed.

Property retention. The relationship between materials properties and component performance characteristics must be determined. In addition, a more complete understanding of how well advanced materials retain their properties after forming or processing must be developed. Standard test methods are needed for most materials, especially to evaluate and characterize mechanical and environmental durability.

Corrosion. Corrosion is a significant contributor to the cost of maintenance of heavy vehicles. The current anti-corrosion electrocoating systems and painting systems, as well as the corresponding processes, are among the most complex, expensive, and environmentally unfriendly components of a vehicle production facility. They also constitute major components of the total vehicle production cost. Research is required to develop materials that are resistant to both general and galvanic corrosion. Low-cost, durable coatings are needed.

In addition to the pervasive needs already described, the following critical R&D needs have been identified.

Light metals (aluminum, magnesium, titanium):

- Aluminum alloys with higher modulus, increased ductility, increased fatigue and corrosion resistance, and enhanced superplastic properties
- Magnesium alloys that have improved high-temperature properties and are corrosion-resistant
- Wrought magnesium alloys with improved strength and toughness
- Improved formability of aluminum and magnesium alloys
- A better understanding of the relationship between impurities and properties of titanium alloys to enable development of low-cost alloys for heavy vehicle applications

Advanced materials (MMCs and ultralight materials):

Ultralight materials are a specific class of engineered materials that includes sandwich structures (metal-polymer, metal-metal, polymer-polymer), metal foams, honeycombs, and closed-metal-cell composites. These materials offer the potential for ultralight weight components. In addition, they can offer improved energy management capabilities for crashworthiness and improved structural dynamics performance. Required improvements include

- Improved materials with uniform, consistent properties
- Improved databases and design methodologies
- Aluminum foam sandwich structures

High-strength steels/stainless steels:

New advanced high-strength steels, as well as existing stainless steels, offer potential for lightweighting. However, the heavy-vehicle industry is somewhat unfamiliar with these materials. A better understanding of their potential and behavior is required for increased acceptance. Developments are required in the areas of

- Alloys with enhanced formability
- Corrosion resistance of advanced high-strength steels to meet heavy vehicle requirements, and coatings compatible with these materials
- Databases and design guidelines for stainless steels

Reinforced polymer composites:

High-priority needs include

- Lower-cost carbon fiber and high-performance resin systems, including the capability to produce Class A surface parts
- Improved databases and design guidelines
- Improved understanding of standardized materials specifications and product forms
- Durability requirements and the response of materials to fabrication, painting, assembly, and service environments
- More recyclable composites

Unreinforced polymers:

R&D focus areas should include

- Certified, standardized product forms
- Improved high-temperature properties for many resin systems and ways of strengthening the matrix
- Higher-stiffness resin systems or methods to reduce creep relaxation

- Recycled materials with more predictable and consistent properties
- Materials with increased ultraviolet resistance and tolerance for weather- and impact-induced damage to simplify, reduce, or eliminate painting in the vehicle production and service repair processes
- Materials with improved high-temperature performance to facilitate faster production and improved performance and durability in the vehicle

Manufacturing
Discussions of manufacturing issues related to body and cab structures also identified a number of needs common to more than one material.

Tooling. Lower-cost tooling is needed for shape forming of all materials, e.g., casting of magnesium and aluminum, stamping of aluminum, forming of wrought aluminum and magnesium, and composite processing. This tooling should reflect the low to medium truck production volumes, along with more rapid tooling development processes that shorten tooling lead-time and reduce or eliminate prototype manufacturing development steps.

Modeling and simulation. Advanced modeling and simulation tools that reduce or eliminate manufacturing prototype process time and cost are needed for a broad range of materials and product forms.

Manufacturing guidelines. Improved manufacturing knowledge bases are needed that can predict the effects of manufacturing on materials properties and performance and provide feedback to design and modeling.

Hybrid materials. To reduce cost, high-speed automated manufacturing techniques are needed for advanced hybrid composites that combine low-cost glass and other reinforcement with carbon fiber, composites that combine glass or carbon fiber with lightweight metals, and combinations of these materials systems.

Joining and assembly. Modeling and simulation tools for joining, assembly, and associated processes are needed to provide design flexibility for advanced hybrid structures. This will enable the optimum use of advanced metals and composite materials in cab structures.

Durability, maintenance, and repair. Manufacturing, joining, and assembly technologies that maximize durability and reduce maintenance and corrosion are needed for all cab body materials. Manufacturing processes that consider and facilitate future maintenance and repair need to be developed.

Design. Design for disassembly methodologies needs to be developed to facilitate maintenance and recyclability.

The following materials-specific manufacturing requirements have also been identified.

Light metals (aluminum, magnesium, titanium):

- Manufacturing methods that increase the ability to form aluminum and other lightweight/high-strength materials into more complex parts and components, for example, low-cost processes such as superplastic forming, electromagnetic forming, electropulse joining, hydroforming, and variable cross-section extrusion and shaping
- Processes that enhance the formability of magnesium alloys
- Large, thin-wall casting technology to produce lightweight, high-strength and -stiffness metal parts with improved control of shape, dimensions, and material properties

Advanced materials:

- Manufacturing and assembly processes for incorporating engineered ultralight materials into vehicle structures

High-strength steels/stainless steels:

- Advanced low-cost manufacturing methods for high-strength steels and stainless steels, including hydroforming, roll forming, tailored blanking, and so on.
- Adhesive bonding, combined with spot welding or riveting of steel, for improved structural performance

Reinforced polymer composites:

- Manufacturing methods that reduce the material properties variability and improve surface characteristics of fiber-reinforced plastic components
- Sheet molding compound (SMC) manufacturing processes that allow the use of thinner panels and structures while retaining required Class A surfaces
- Liquid molding and SMC methods, adaptable to lower production volumes for carbon-fiber-reinforced composites, including the capability to produce carbon-fiber-reinforced parts with Class A surfaces
- Modeling and simulation tools, tied to material and design databases, for the development of advanced carbon-fiber and hybrid composite manufacturing techniques
- More-robust manufacturing processes, optimized for the heavy-vehicle industry

Unreinforced polymers:

- New manufacturing methods for thermoplastic composites and core structures

Maintenance, Repair, and Recycling
Market dynamics and incentives must be understood as the major drivers for maintenance, repair, and recycle decisions. Discussions on these three related topics identified the following needs. Maintenance and repair issues for cab structures are primarily associated with durability, i.e., fatigue-related failure, and corrosion. Major damage modes for trailers are structural damage from impacts (driver-related), structural damage due to forklift impacts, and corrosion. Most of the following needs are common to all materials.

- Methods to protect against all forms of corrosion
- Special procedures for dealing with galvanic effects if new materials are substituted for existing materials
- Repair procedures for new materials
- Accelerated testing methods to simulate materials and structural performance in the operating environment
- Data on repair frequencies, costs, and incentives for various repair types
- Improved recycling technologies for new lightweight materials, especially for higher-cost materials such as carbon fiber in reinforced composites
- Techniques for separating hybrid materials structures to allow for easy and effective recycling
- Designs for cost-effective disassembly for maintenance, repair, and recycling

Summary of R&D Needs—Body and Cab Structures

Cab structures represent key materials and manufacturing challenges for heavy-vehicle manufacturers. Development of body structure design; selection of materials and corresponding manufacturing processes; assembly; and in-service performance, durability and maintenance are the direct responsibility of the truck OEMs. Body structures and associated styling are considered a differentiating aspect of the manufacturers' vehicles and are therefore of great importance to heavy-truck OEMs. Achieving a goal of 20% reduction in body structure weight is technically feasible for medium- and heavy-duty vehicles. However, weight reduction must be accomplished with minimal cost, durability, and maintenance penalties. The use of new materials and cost-effective manufacturing technologies will be an important contributor to implementing lighter-weight, more-efficient and cost-effective body materials and designs. Key R&D needs in body and cab structure include

- Lower material cost
- User-friendly databases with uniform architecture for all materials that can enable both the design and the simulation of materials behavior during the manufacturing process and for the final product
- Design data and methodologies for "hybrid material structures" that take advantage of inherent characteristics of the materials and allow optimization for weight, performance, and cost
- New alloys with improved, uniform, and consistent properties (stiffness, strength, fatigue resistance, formability)

- Standardized materials specifications and product forms (especially for polymer composites) that are suited to heavy-vehicle manufacturing and performance needs
- Enhanced durability for all materials to reflect the duty cycles of heavy vehicles
- Low-cost corrosion-resistant materials and coatings
- Polymer materials with increased ultraviolet resistance and tolerance for weather and impact damage to simplify, reduce, or eliminate painting in vehicle production and field repair processes
- Advanced stamping, forming, and joining technologies for metallic components that maximize component function, reduce part count and assembly cost, and reduce weight while using significantly cheaper and more flexible tooling approaches
- Modeling and simulation tools that assist in efficient design of body structures; eliminate time-consuming prototype development; and predict the properties and in-service performance of manufactured structures, including high-rate deformation for crashworthiness design
- New, innovative manufacturing, joining, and assembly technologies for carbon-fiber composites and hybrid material structures, including the capability to produce Class A surfaces
- New manufacturing technologies and their associated material systems that provide product design flexibility, improved durability, and corrosion resistance in real-life truck applications
- Accelerated testing methods to simulate, with fidelity, materials and structural performance in operating environments that are acceptable to truck OEMs
- Repair procedures for new lightweight materials
- Cost-effective disassembly for maintenance, repair, and recycling

CHASSIS STRUCTURES

Background

Chassis structures for medium- and heavy-duty trucks and trailers are required to support the vehicle payload, react to powertrain loads, provide the foundation for the suspension system and cab structure, and provide mounting points and space for a variety of vehicle subsystems and accessories. In addition, the basic chassis design must accommodate a large combination of frame lengths, axle placements, frame crossmember designs and placements, and cab mounting systems. During the life of many Class 8 trucks, it is not uncommon for the vehicle frame to be reconfigured for a different vehicle application, such as conversion from an over-the-road Class 8 tractor to a vocational truck application. As a result of the many design and service requirements, current frame design consists of a separate ladder-type frame with multiple bolted crossmembers. Frame rails are typically heat-treated (in North America) alloy steel "C"-channels that provide flexible manufacturing by allowing readily adjustable rail length, variable crossmember positioning, and flexible positioning of bolted accessories. Although of relatively simple design and manufacture, frame structures are subjected to very high loads, must meet extreme durability requirements, and are exposed to the most severe corrosion conditions. The increased use of a complex mix of ice-clearing chemicals on interstate trucking routes has significantly increased the corrosion of chassis components, especially on trailers. The integrity of the chassis frame structure is essential for preservation of the overall vehicle integrity in all situations where the vehicle is exposed to extreme service conditions or accidents. The vertical and lateral bending stiffness of the frame structure must be maintained at the current levels, and in some instances even increased, to preserve or improve the ride, handling, and braking dynamics performance. This requirement presents significant challenges from the vehicle design and materials perspectives in pursuing minimum weight. Because of their robust, largely steel construction, frame structures represent an opportunity for significant weight savings; however, cost, manufacturing flexibility, safety, and vehicle performance and durability must be maintained.

Goals

The general weight reduction goal for medium- and heavy-duty trucks is an overall vehicle weight reduction of at least 20% while maintaining the performance, safety, and durability of the vehicle. Because of the many, conflicting requirements for medium- and heavy-duty truck frames, weight reduction accomplished by using lighter-weight materials and advanced manufacturing techniques must have only minimal impact on vehicle functionality. In addition to the weight reduction goal, a key manufacturing R&D goal would be to focus on manufacturing flexibility, designs, coatings, and joining methods that significantly improve corrosion performance, corrosion fatigue, fretting, and overall vehicle frame maintenance.

Technical Approach

Materials Development

The discussion of materials needs for chassis structures identified some of the same needs that were identified for body structures: reduced cost of primary materials, improved design and simulation databases, better fundamental understanding of property retention after forming operations, and corrosion protection/mitigation, especially with respect to more aggressive ice-clearing chemicals. In addition, a better understanding of mechanical and environmental durability and damage tolerance is required. Enabling technologies such as surface modification and coatings are needed to reduce wear, corrosion, and fretting in chassis structures and trailers. The coatings and surface treatments must be low-cost, durable, and maintenance-free. Advanced, non-bolted joining methods are needed, such as electromagnetic pulse joining, friction stir welding, retrogression heat treatment (with compression joints), and advanced adhesive bonding. These also must be low in cost and must require minimal maintenance.

The following more specific R&D needs were also identified.

Light metals (aluminum, magnesium, and titanium):

- Better design concepts that take advantage of the inherent properties of aluminum and allow optimization of weight
- Advanced casting methods for aluminum and magnesium that result in thinner, lighter-weight castings with improved fatigue and corrosion resistance for chassis components, brakes, wheels, and hubs
- Alloys with higher strength and toughness
- Improved fatigue-resistant aluminum alloys
- Aluminum alloys with higher strength and ductility to avoid failure in overload conditions
- Alloys and coatings that are more resistant to corrosion, especially the effects of ice-clearing chemicals

Reinforced polymer composites:

- Wear- and impact-resistant materials
- Better materials constitutive models and processing models
- A fundamental understanding of the effect of holes on carbon-fiber composites
- A more fundamental understanding of environmental impacts on carbon-fiber-reinforced composite materials

High-strength steels/stainless steels:

- Material-specific guidelines for improved designs that take full advantage of the properties of high-strength steels
- Improved coating technologies and corrosion-resistant alloys to mitigate the effects of ice-clearing chemicals on roadways

- Advanced casting methods that result in thinner, lighter-weight castings with improved fatigue resistance for chassis components, brakes, wheels, and hubs
- Evaluation of stainless steels for chassis components, and improved databases and design guidelines to accelerate acceptance by industry

Advanced materials (MMCs and ultralight materials):

- More complete materials models
- Lower-mass MMCs
- Design guidelines for laminate materials and corrugated structures are needed to allow design engineers the flexibility to use these engineered materials when appropriate

Hybrid materials systems (e.g., multi-fiber composites, polymer-metal combinations):

- Improved databases, design guidelines, and modeling and simulation tools
- Methodologies to mitigate galvanic corrosion

Manufacturing

The discussion of manufacturing issues for chassis components focused on frames and identified several prevalent issues.

Current frame manufacturing techniques result in frame rails that have a non-variable cross-section and sectional properties, while actual frame loading conditions vary as a function of vehicle length and configuration.

Many common frame materials and joining techniques are subject to fatigue, corrosion, and fretting corrosion damage, leading to overdesign. The result is increased frame weight and maintenance and decreased energy efficiency.

Advanced lightweight materials, particularly continuous fiber composites, are subject to significant reductions in strength and durability when conventional fastening and joining techniques are used, and composite joining methods currently do not offer the manufacturing flexibility required by truck customers.

Available design, modeling, and simulation tools are inadequate for optimization of frame structures and improved joint design and durability predictions, especially when a number of different materials are used in an assembly.

Some more specific manufacturing needs are listed below for the various types of materials.

Light metals:

- For both the tractor and trailer, improved manufacturing methods for aluminum frame rails and crossmembers that allow variable cross-section shapes and result in improved fatigue life and resistance to fretting and corrosion
- Low-cost manufacturing methods for selected titanium chassis components
- Low-cost conformal shaping methods such as superplastic forming for fuel tanks, battery boxes, and other accessories

Reinforced polymer composites:

- Lightweight composite and hybrid composite frame rails that provide a high stiffness-to-weight ratio and are at the same time durable and allow frame customization and manufacturing flexibility
- Joining methods for lightweight frame members that maintain the properties of the parent materials; reduce or eliminate corrosion, fretting, and fatigue at the frame joints; and allow frames to be customized and reconfigured during manufacture and service life
- Low-cost polymer composite manufacturing methods for thermoplastic composite materials for fuel tanks, battery boxes, and other accessories
- The capability to pultrude variable cross-section curved surfaces

Hybrid materials systems (e.g., multi-fiber composites, polymer-metal combinations):

- Low-cost manufacturing techniques for advanced hybrid materials components and assemblies
- Improved models for joint design and fabrication
- Both system-level and component-level design and manufacturing modeling tools

Maintenance, Repair, and Recycling

The needs identified for chassis structures can be categorized into four major groups: corrosion and environmental effects; fatigue, including crack initiation and propagation; gross overload; and abuse due to tool drops, hole modification, and welding/heating.

The following are some materials-specific R&D needs.

Light metals:

- Improved methods of detecting and monitoring corrosion to replace visual inspection
- Improved, cost-effective methods for isolation and/or protection from galvanic effects
- Improved repair options for aluminum and other light metals

High-strength steels/stainless steels:

- Low-cost manufacturing methods
- Improved joining technologies for advanced high-strength steels
- Methods for joining steels to other metallic and non-metallic materials

Reinforced polymer composites:

- Improved understanding of corrosion effects on carbon-fiber-reinforced composites (carbon-fiber, matrix, interface) as well as the development of repair techniques
- Improved methods for detection of impact or fatigue damage in polymer composites and methods for repair
- Predictive maintenance methodologies

High-strength steels:

- Procedures for repair of fatigue damage
- Guidelines for determining the effects of post-manufacturing welding/heating

Summary of R&D Needs—Chassis Structures

Chassis structures—taken to include fuel system, battery boxes, and other chassis-attached accessories—represent approximately 15% of the overall tractor weight. They are characterized as large, built-up structures that must serve multiple vehicle functions, are highly loaded, and must operate under extreme durability, fatigue and corrosion conditions. With few exceptions, medium- and heavy-duty frame structures are built around a pair of "C"-channel steel rails, with multiple bolted crossmembers along the length of the frame. As a result, the frame rail and crossmembers represent the largest opportunity for significant weight reductions in the frame structure. Many technologies developed for the tractor frame could also be applied to lightweight trailer designs. Despite the weight reduction potential, the requirement for low-cost manufacturing flexibility (customization), the customer requirements for vehicle configuration, and the need for improved durability and lower maintenance make the application of lighter-weight materials and designs a challenging manufacturing R&D area. Key areas for R&D include

- Improved databases and design guidelines for all materials that allow optimization of structures for weight, cost, and performance
- Improved alloys with fatigue resistance, durability, and strength
- Advanced casting technologies for light metals and high-strength steels that result in thinner, lighter castings with improved fatigue and corrosion resistance
- Corrosion-resistant materials, advanced coatings, and other corrosion protection methods to mitigate the effects of corrosion induced by ice-clearing chemicals used on roadways

- Better materials constitutive and processing models for reinforced polymer composites
- Advanced frame rail and crossmember manufacturing technologies for all materials that can significantly reduce frame weight while meeting and improving vehicle safety, performance, durability, and maintenance requirements and design flexibility
- Joining methods for lightweight metal and polymer composite frame designs that maintain the required manufacturing flexibility while improving joint efficiency; reducing material property degradation; and significantly improving the fatigue, fretting, and corrosion performance of the frame structure to allow designers the flexibility to use these materials in structural applications
- Improved design, modeling, and simulation tools that can be used to optimize frame design; manufacturing processes for advanced lightweight materials, especially hybrid materials systems; and advanced joining methods to reduce frame weight and facilitate the use of alternate frame materials
- Improved, cost-effective methods for isolation and/or protection to avoid galvanic corrosion
- Repair procedures, including field repair, for light metals, polymer composites, high-strength steels, advanced materials such as MMCs, and hybrid materials systems
- Improved methods of detecting and monitoring corrosion to replace visual inspection
- Preventative maintenance methodologies

SUSPENSION AND DRIVETRAINS

Background

Drivetrain and suspension components represent approximately 15–20% of the weight of a Class 8 tractor and a somewhat smaller percentage of the weight of medium-duty vehicles. Included in the suspension/drivetrain category are the drive axles, typically two per tractor for Class 8; the steer axle; lift axles (if required); vehicle service brakes; the suspension system that is used to locate and control the suspension and drivetrain; and the transmission, clutch assembly, and drive shafts. As with frame structures, suspension systems and drivetrains can be highly customized and unique to the customer; to some degree, changes in suspension and drivetrain configuration and location can occur during the life of the vehicle. Current drive axles and many suspension components are manufactured from steel or iron castings or fabricated from steel, and they incorporate high-strength precision gears, bearings, shafts, and fasteners. Although lighter-weight materials have the potential to reduce drivetrain weight, functional requirements make replacement of current iron-based materials difficult. Finally, improvements in brake friction materials are of great importance and have the potential to save weight and improve vehicle safety and maintenance.

Goals

The overall program goal is to reduce the weight of a tractor/trailer combination by at least 20% while maintaining vehicle performance, safety, and durability. A typical Class 8 suspension and drivetrain system weighs approximately 3000 lb, so a reduction of approximately 600 lb would be the target goal. Because of the high loads and torque transmission requirements placed on drivetrain and suspension components, opportunities to replace the steel and iron currently used in many of the components will require major system-level design changes.

Technical Approach

Materials Development
As was the case in the previous two sections, the discussion of developments required in materials technologies for suspension systems and drivetrains identified several needs common to more than one material. These common needs include lower-cost primary materials and materials processing technologies for those materials; improved databases, design methodologies, and modeling and simulation capabilities, especially structure-property relationships; a more complete understanding of property retention after processing; improved resistance to general and galvanic corrosion; enhanced ability to design and fabricate hybrid material structures; and improved joining techniques for similar and dissimilar materials.

Additional needs for specific materials were also identified and are listed as follows by material.

Light metals (aluminum, magnesium, and titanium):

- Higher-strength, tougher alloys
- Aluminum/steel cladding technology
- Magnesium alloys with improved creep resistance and/or higher strength
- A larger variety of low-cost titanium alloy formulations for applications such as steer axle springs, tie rods, air suspension springs, and high-temperature components
- Titanium alloys with improved sliding and fretting wear resistance
- Improved surface treatments

Advanced materials (MMCs and ultralight materials):

- Aluminum foam sandwich structures
- The machinability of MMCs
- The low-temperature performance of carbon-carbon composites for brake applications
- New brake materials with the right combination of strength and stiffness, thermal conductivity, and wear and corrosion resistance

Advanced high-strength steels:

- Innovative, reliable, variable-wall-thickness casting methods for large, high-strength steel and ductile iron castings
- Technologies for producing "cleaner" steels with improved fatigue resistance
- Technologies for joining castings and for joining cast products to wrought products

Reinforced polymer composites:

- Composites with improved resistance to abrasion and environmental degradation
- Machineable polymer systems
- Techniques for surface hardening of polymer composites
- Advanced moldable composites that do not require performs, and low-cost, nearly continuous (drapeable) preforms

Manufacturing

Discussions of manufacturing issues for suspension systems and drivetrains focused on the following R&D needs.

- Low-cost surface modification, treatments, and coatings for reduced wear, reduced friction, and improved surface properties
- Manufacturing technologies that enable the use of more corrosion-resistant materials and improved protective coatings and the reduction of dissimilar material reactions

- Manufacturing techniques that can be applied to higher-strength steel and aluminum alloys that have improved fatigue and scuffing/fretting resistance
- Lower-cost net-shape manufacturing technologies for high-fiber-volume carbon-fiber and hybrid composites for use in propshafts, suspension links, and other high-stress components
- Manufacturing techniques for low-cost titanium for use in springs, including cost-effective methods for manufacture of tubular titanium spring elements
- Research into manufacturing methods that facilitate the use of lower-cost carbon–carbon and carbon–silicon carbide materials in advanced brake systems for heavy vehicles and trailers
- Post-shaping methods for thermoplastic composite materials that allow complex net-shape components to be formed from simple preform materials
- Cost-effective manufacturing methods, e.g., extrusion technologies, for processing of low-cost cast aluminum MMC materials into propshafts, fifth wheels, and other components

Maintenance, Repair, and Recycling

Issues for suspension/drivetrain applications are focused on inexpensive maintenance and repair. Most of the repairs are corrosion induced and are increasingly attributable to the effects of an aggressive mix of ice-clearing chemicals. Some specific needs are listed as follows.

- Repair processes that do not compromise heat treatment of metallic components
- Reversible joining technologies for composites, with improved understanding of the mechanics near holes and joints, to enable increased use of these materials
- Inexpensive, field-deployable nondestructive evaluation and repair techniques

Summary of R&D Needs—Suspension and Drivetrains

Suspension and drivetrain components represent good candidates for weight reduction through the application of high-strength, lightweight materials. However, because of the high power-transmission loads and reliability requirements, many key components are likely to continue to be manufactured from iron-based materials. They include gear sets, pinions, bearings, and high-strength bolts. The combinations of dissimilar material systems that are found in most drivetrain and suspension systems—combined with their exposure to wet, corrosive and abrasive road conditions—present significant corrosion challenges. From the owner/operator perspective, a top R&D priority for suspension and drivetrain materials and manufacturing would be to improve the corrosion resistance of components, improve joining methods, and prevent dissimilar material reactions in corrosive environments. Manufacturing methods for high-temperature, wear-resistant brake materials represent a good R&D opportunity; and advances in this area will provide weight savings, as well as improvements in vehicle safety. General R&D areas for suspension and drivetrain systems include

- Alloys with better wear resistance, higher strength and stiffness, and improved durability

- Improved protective coatings, surface modifications, or materials with improved corrosion characteristics, and methods for prevention of galvanic corrosion between dissimilar materials in suspension/drivetrain systems
- Improved casting technologies that provide flexibility in controlling and varying the wall thickness of large drivetrain and suspension castings to provide the opportunity for reduced weight and improved performance
- Manufacturing technologies for advanced cermets and carbon–carbon brake friction materials that provide the dual benefits of reduced weight (sprung weight) and improved vehicle safety
- Enhanced ability to design and fabricate hybrid material structures
- Lower-cost net-shape manufacturing technologies for composites with improved resistance to abrasion and environmental degradation for use in highly stressed components
- Joining technologies for similar and dissimilar materials to enable the introduction of hybrid material structures
- Inexpensive, field-deployable systems that allow early detection of degradation and timely preventive maintenance

FUNDING PLAN

The R&D Plan provides an overview of some of the major materials and manufacturing challenges that must be met to reduce parasitic vehicular energy losses that are due to the weight of heavy vehicles. These reductions in the overall weight of vehicles are a necessary component in the strategy to achieve the fuel efficiency and emissions reduction goals of DOE. The following table shows the estimated funding needed for the next five years to accomplish the weight reduction goals established by the HS/WR Materials Program for heavy vehicles. These estimated funding levels for materials development; manufacturing; and maintenance, repair, and recycling will provide the resources necessary to overcome the barriers to the introduction of lightweight materials in heavy vehicles. The estimates were not constrained by a pre-assigned budget cap but were based on engineering judgment, consistent with program goals and schedules. The estimated funding level for FY 2003 is significantly higher than the approved budget. Note also that significant increases in funding will be required for the years 2004–2008 in order to meet the program objectives in a reasonable timeframe.

High-Strength/Weight Reduction Materials Program funding requirements by fiscal year							
Technology	**Fiscal year ($ in thousands)**						
	2003	**2004**	**2005**	**2006**	**2007**	**2008**	**Total**
Materials Development	6,500	10,000	10,000	10,000	8,500	6,000	51,000
Manufacturing	10,500	12,000	15,000	16,000	13,000	10,000	76,500
Maintenance, repair, recycle	1,000	2,000	3,000	4,000	2,500	2,000	14,500
Total	**18,000**	**24,000**	**28,000**	**30,000**	**24,000**	**18,000**	**142,000**

Note: The funding estimates shown are the government share of the project cost. It is assumed that industry cost sharing will match the government contribution.