CHARACTERIZING AND ENHANCING THE SAFETY OF FUTURE PLASTIC AND COMPOSITE INTENSIVE VEHICLES (PCIVs)

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ABSTRACT

There is concern that a trend toward smaller, lighter, fuel-efficient vehicles could adversely affect overall fleet safety. Since 2006, the U.S. Congress has directed the National Highway Traffic Safety Administration to "*examine the possible safety benefits of lightweight plastic and composite intensive vehicles (PCIVs)*" with Federal and industry stakeholders. This paper identifies near-term research priorities and partnership opportunities to facilitate the deployment of safe and energy efficient PCIVs by 2020.

A critical literature review and focused survey of subject matter experts identified knowledge gaps on automotive composites crashworthiness and consensus safety research priorities. Initial results were published in a 2007 PCIV Safety Roadmap report with milestones to 2020. The roadmap was developed to address development of plastics and composites crashworthiness test standards, improved computational simulation tools, and automotive design strategies.

Additional inputs on key safety issues for automotive composites were obtained from an August 2008 experts' workshop, which examined in depth critical near-term research priorities and strategies to meet crash occupant protection challenges for future PCIVs.

There is broad consensus that future PCIV structural composites with high energy absorption may enhance crash safety by preserving occupant compartment strength and protecting crush space. Near-term cooperative research is needed to:

- improve understanding of composite failure modes in vehicle crashes,
- develop a database of relevant parameters for composite materials, and
- enhance predictive models to avoid costly overdesign.

PCIV safety research is synergistic with ongoing NHTSA research (hydrogen and alternative fuel vehicle safety, integrated safety, crash occupant protection), the US Government (DOE/USCAR consortia), and the global automotive industry and research community.

This paper concentrates on safety-related research issues, assuming that other potential barriers to PCIV deployment (e.g., economic viability, manufacturability, sustainability) will be resolved. An updated safety roadmap and supporting cooperative research efforts are planned to facilitate the development and deployment of PCIVs with equal or superior crash safety by 2020.

INTRODUCTION

In fiscal year 2006, the United States Congress directed the National Highway Traffic Safety Administration (NHTSA) to *"begin development of a program to examine the possible safety benefits of lightweight Plastics and Composite Intensive Vehicles (PCIVs)*" and to develop a foundation for cooperation with the Department of Energy (DOE), industry and other automotive safety stakeholders. NHTSA tasked the Volpe National Transportation Systems Center (Volpe Center) to conduct focused research, in cooperation with industry partners from the American Plastics Council (APC), now the American Chemistry Council - Plastics Division (ACC-PD).

NHTSA's goal is to evaluate the potential safety benefits of plastics and composites applications in the emerging lighter weight, more fuel efficient and environmentally friendly vehicles. The PCIV safety research project is synergistic with ongoing NHTSA research efforts (hydrogen and alternative fuel vehicle safety, integrated safety, crash occupant protection). PCIV safety research also supports global and national efforts to improve vehicles' energy efficiency and preserve the environment with equal or better safety performance and affordability.

THE PCIV SAFETY RESEARCH ROADMAP

In 2007, the Volpe Center published "*A Safety Roadmap for Future Plastics and Composites Intensive Vehicles (PCIV)*" [1]. The report described the approach, activities, and results of an evaluation of potential safety benefits of PCIVs. The safety-focused effort complemented earlier and more general technology integration roadmaps developed by ACC-PD [2].

A simplified summary of the 2020 PCIV Safety R&D Roadmap priorities is shown in Figures 1 and 2. Figure 1 summarizes the strategic research priorities and timeline for 2020 PCIVs while Figure 2 addresses options to enhance PCIV safety performance.

Strategic Priorities for 2020 Plastics and Composite Intensive Vehicles Safety Assurance

Major Challenges	Perform focused, coordinated and integrated safety research, development, test, and evaluation Program to improve crash-safety performance of plastic/composite components and subsystems for a 2020 PCIV.

Research, Development, Test, and Evaluation Priority

	Near-term (2007-2010)	**Mid-term (2010-2015)**	**Long-term (2015-2020)**
Materials Selection	Perform research and technology to address "knowledge gaps" on crash-safety performance of PC materials	Modeling and simulation to verify and validate plastic/composite crash safety in structural, semi-structural applications	Demonstrate integrated safety performance for prototype PCIV to enable commercial deployment
	• Standardize testing protocols for composite materials	• Validate plastic/composite materials choices in safety applications	• Industry crash-test and self-certify PCIV safety
Testing Crash Performance	• Characterize mechanical behavior of plastic/composite materials in safety applications	• Prototype and test components (door panels, roof, front and back "crush boxes")	• Identify and overcome PCIV crash-compatibility problems for all occupants
	• Establish comprehensive Database for light-weighting materials options	• Verify and validate for baseline PCIV design to evaluate integrative safety system performance	• Demonstrate enhanced PCIV safety performance for older occupants (using advanced dummies)
PCIV Integration	• Refine predictive engineering tools for Modeling and Simulation of PCIV components and system crash performance	• Devise and evaluate special crash- protection needs for older occupants	• NHTSA verifies PCIVs compliance with crash- safety regulatory requirements
Milestones		• Test Standards Issued • CHM-17 Crash Energy Database Standardized and Current • Modeling and Simulation Crash Safety Tools Available	• PCIV Structural and Propulsion Validated for Realistic Crash Loads • Full PCIV System is Crashworthy • Improved Older Occupants Survivability is Demonstrated

Figure 1: Strategic priorities for 2020 plastics and composite intensive vehicle (PCIV) safety assurance [1]

Enhancing Plastics and Composites Intensive Vehicles Safety Performance With Plastics			
Challenges / Milestones	• Design concepts • Materials screening • Testing standards • Simulations and validation	• Systems integration • Crash safety testing • Performance metrics • PCIV deployment	
Performers	**Near-term (3-5 years)**	**Mid-term (5-10 years)**	**Long-term (10-15 years)**
Industry – Government – University Public Private Partnerships (P3)	Research, Development, and Technology on Automotive Composites	Test & Evaluation Of PCIV Prototype Crash Safety	System Integration of PCIV Safety Technologies 10-15 yrs.
	Develop Testing Standards and Safety Evaluation Tools for PCIV Designs 1 yr.	Crash Safety Verification & Validation Simulations 5-6 yrs.	PCIV Commercial Deployment 15+ yrs.
	Select Lightweight Structural Materials for PCIV 2-3 yrs.	Crash Safety Testing & Validation For PCIV Subsystems and Vehicle 6-8 yrs.	
	Develop PCIV Materials Processing / Parts Fabrication 3-5 yrs.		
NHTSA Role	NHTSA Monitors Progress in Crash Safety Research and Development	NHTSA Evaluates Results of Crashworthiness Verification & Validation	NHTSA Verifies PCIV Crash Safety Compliance (NCAP and FMVSS)

Figure 2: Enhancing plastics and composite intensive vehicle (PCIV) safety performance with plastics [1]

The Volpe Center conducted structured interviews with leading subject matter experts (SMEs), representing a broad cross-section of automotive safety stakeholders. Interviews were complemented by written inputs and supporting materials provided by the SMEs. The process identified priority knowledge gaps and safety research and development (R&D) needs to predict the crashworthiness of automotive composites. The SMEs encouraged NHTSA participation in cooperative research efforts on automotive light-weighting, and in standards development activities for structural polymeric composites.

The Volpe Center also reviewed and summarized the knowledge base on automotive light-weighting materials crash safety, and identified related national and international research programs offering high-leverage partnership opportunities. Federal and industry initiatives identified include the DOE FreedomCAR and Fuel Partnership consortia and the Advanced Lightweight Materials Program [3], which develops strong, lightweight vehicle material options to improve energy efficiency.

There is broad consensus that future PCIV structural composites with high energy absorption may enhance crash safety by preserving occupant compartment strength and volume to optimize crush space. Composite materials standards development efforts are particularly important for designing PCIVs that meet NHTSA crashworthiness requirements and the associated occupant protection challenges.

These roadmaps defined safety-related R&D activities for near-term (three to five years), mid-term (five to ten years) and longer term (ten to 15 years), as well as milestones and metrics for progress towards the successful design, development, and deployment of lightweight, fuel-efficient and environmentally sustainable PCIVs. Near-term cooperative research is needed to:

- improve understanding of composite failure modes in vehicle crashes,
- develop a database of relevant parameters for composite materials, and
- enhance crash damage predictive models to avoid costly overdesign.

The focus of this project was on the identification of PCIV crash safety research needs germane to the NHTSA vehicle safety mission, and complementary to DOE/USCAR industry consortia research on vehicle light-weighting materials [3]. Thus, it was assumed that other potential barriers to PCIV deployment (e.g., economic viability, manufacturability, sustainability) would be resolved by 2020 through other efforts.

Research Needs to Predict the Crashworthiness of Composite Automotive Structures

The safety roadmap development effort identified high-priority research needs for advancing the design and analysis of composite automotive structures for crashworthiness. These would enable greater utilization of automotive plastics and composite materials in future PCIVs. They include:

- Continued refinement of full three-dimensional analysis modeling tools;
- Understanding of how failure and energy absorption are controlled by processes at several length scales;
- Inclusion of all damage modes (and associated failure models criteria) in computational models;
- Consideration of interaction effects in crashes;
- Standardized tests for fatigue, creep, and aging effects;
- Consideration of structural configurations in impact crash performance;
- Understanding issues related to manufacturing and lifetime handling;
- Inclusion of probabilistic aspects of failure; and
- Identification and proper modeling of the actual crash reality (i.e., geometry and force).

Research Needs for Occupant Safety

High confidence in PCIV safety performance characterization will also require research to:

- Improve statistical crash data analysis to understand how severity of injuries and survivability vary with age and identify mitigation options.
- Develop stronger passenger compartment designs with frontal crush boxes.
- Improve the occupant restraints and seating systems to restrict side head movements and limit head and neck injuries.
- Adaptive restraint systems "tuned" to occupant size, weight, and age or fragility.
- Reduce impact loads with customized occupant space (seating, bolsters, belt system) for improved protection and comfort.
- Optimize the design and performance of the combined passive and active restraints system ("sum total of interior passive foams, active air bags and belts").
- Verify that PCIVs would be sufficiently safe in the case of a post-crash fire.

Other industry-identified priority PCIV safety applications include:

- Four-point seat belts and seat belt limiters to protect aging drivers;
- Plastics that have strain-to-fail characteristics similar to steel that are not strain rate or temperature sensitive;
- Vehicle structure that produces a similar vehicle crash pulse as current production vehicle structures using metal (aluminum or steel);
- Enhanced visibility (glass composites to reduce nighttime glare); and
- Pre-crash sensors for gentler deployment of safety devices (smart air bags, load limiters, inflatable seat belts).

Near-Term Safety Research Priorities

The near-term (three to five year) PCIV R&D priorities identified in the roadmap process include:

- Stronger foam filling on side doors and posts, combined with soft foam padding on interior surfaces to mitigate side impact intrusions;
- Rigid "structural foams" to fill in and reinforce metal roof structure and pillars in order to mitigate rollover injuries;
- Use of lightweight plastic structures in roofs to lower the center of gravity of top heavy vehicles;
- Improvement of cushioning and belt restraints (e.g., use woven cylindrical seat belts, four-point attachments);
- Use of "smart" materials for "smart" safety devices; and
- Standardization to high-performance safety subsystems (such as head restraints, seat system designs, etc.).

A cross-functional PCIV industry team identified additional near-term research topics to address specific NHTSA safety requirements in the relevant Federal Motor Vehicle Safety Standards (FMVSS) through the use of:

- Interior plastics and foams to address applicable NHTSA safety requirements (e.g., FMVSS 201 - Occupant protection in interior impact; 207 - Seating systems; 208 - Occupant crash protection; and 214 - Side Impact protection);
- Vehicle body enhancement foams that address NHTSA crash safety performance regulations (e.g., FMVSS 208, 214, and 216- Roof crush resistance);
- Seatbacks responsive to standards (e.g., FMVSS 202A - Head restraints); and
- Bumper structural strength for both occupant and pedestrian protection in low speed crashes (49 CFR Part 581 – Bumper Standard).

Mid-Term Safety Research Priorities

The mid-term (five to ten year) R&D priorities identified in the roadmap process include:

- Validated composite components;
- OEM design guidelines for automotive composites;
- Validated crashworthiness performance of Carbon Fiber Reinforced Composites using improved:
  - Testing standards for high-rate impacts;
  - Energy absorption predictive tools;
  - Three-dimensional computer modeling of material behavior versus time;
  - Durability testing standards;
  - Verification in full-scale field testing; and
  - Integrated designs for active seat belt, air bags, and seat systems to enhance protection in side impacts.
- Development of new PCIV designs (three to seven years); and
- Marketing of successful PCIV prototype (seven to ten years).

The industry team specified priorities such as:

- Interior and exterior plastic applications;
- New Federal Motor Vehicle Safety Standards (FMVSS) for vehicle occupant protection development that appropriately accommodate PCIVs; and
- Vehicle body engineered systems to support new FMVSS requirements.

Long-term Safety Research Priorities

The long-term (ten to 15 year) R&D priorities identified in the roadmap process include:

- Utilization of improved fiber reinforced plastics for rigid door panels, to tailor energy absorption to depth of deformation in side crashes;
- Improved vehicle occupant protection;
- Reduce the mass of the entire fleet, or reduce the mass of the heaviest vehicles;
- Improved passive and active safety devices that can compensate for any disadvantage of lighter weight and smaller size cars in collisions with larger and heavier vehicles; and
- Use of advanced materials (e.g., nano-composites, hybrid polymers, bio-polymers, and natural fiber materials) in automotive safety applications, but only to the extent they can meet crash and performance requirements.

THE 2008 PCIV SAFETY WORKSHOP

In August 2008, NHTSA sponsored and the Volpe Center organized and hosted a workshop for subject matter experts (SME) entitled *"The Safety Characterization of Future Plastic and Composites Intensive Vehicles"* [4]. Its primary purpose was to obtain and integrate inputs and clarifications to the roadmap process that would facilitate the definition, characterization, and quantification of safety benefits expected from using advanced plastics and composite materials for the next generation of mass-market lightweight, fuel-efficient vehicles. A related goal was to gather lessons learned from the use of structural composites in high-end, high-performance sports and racing cars that could be applied to mass-market PCIVs.

Approximately 50 leading experts on automotive safety and advanced materials representing government, industry, academia, and standards developing organizations attended the workshop. Presentations and focused discussions contributed to refining the near-term vehicle safety research roadmap, to facilitate safety-centered PCIV design and deployment by 2020. The workshop findings will broaden, deepen and clarify the PCIV Safety Roadmap research and development priorities, and better define relevant PCIV safety metrics and milestones. [4]

The thematic presentations were followed by focused panel discussions that engaged the experts on specific PCIV safety issues in order to:

- Build consensus on the PCIV Safety Roadmap research and development priorities
- Identify, characterize and quantify the potential safety benefits of proposed lightweight composites in emerging PCIV design concepts;
- Determine safety challenges and safety technology opportunities for emerging and future PCIV concepts.

Industry experts noted that plastics consume just 3% of US oil and natural gas and account for only 10% of the material in automobiles, but offer the possibility of improved fuel-efficiency (through mass reduction), design flexibility, durability, environmental sustainability through end of life (EOL) recyclability, and enhanced crash safety. Additional safety-enhancing applications were cited such as plastic bumpers and fenders to improve pedestrian safety in crashes.

Refined Definition of PCIVs

The focused discussion after the first technical session addressed the definition of PCIV. There was the sense that, for the time being, systems such as the engine block were not plausible applications for intensive utilization of plastics. Other vehicle systems were more amenable to redesign in plastics and composites. Attendees representing Original Equipment Manufacturers (OEMs) and material suppliers indicated that a minimum of 30% to 40% (by weight) plastics and composite content in one or more subsystems beyond interior trim could qualify a vehicle as a PCIV. Note that this is less stringent than the DOE/USCAR light-weighting "Factor of Two" goal desired for improved fuel efficiency.

Automotive Safety Applications of Plastics and Composites

Attendees were asked to expand on the list of applications in which the use plastics and composites could enhance vehicle and fleet safety. The safety benefits for the structural and semi-structural applications in the Body In White (BIW) were treated separately from those applications designed to sustain impacts and the interior applications of padding intended to redistribute, deflect and cushion impact forces on the occupants (thicker, softer plastic foams, air bags, and restraints).

Data indicate that smaller and lighter vehicles are more “crash-involved” (despite presumed enhanced maneuverability) and therefore less safe in collisions with heavier and larger vehicles [5]. Some experts believe that weight disadvantage in crashes could be offset by maintaining size and crush space to protect the occupants. The use of strong but lightweight composites could improve both safety and fuel efficiency. At any given crash velocity, lighter cars have less crash energy. Reduced vehicle weight across the fleet could also reduce the weight disparity and improve crash safety. [6]

A safety benefit of carbon-fiber composites (CFC) in vehicle structures is superior specific energy absorption (SEA). Formula 1 racing cars have strong CFC nose cones for driver compartment crush protection, but these nose cones may not be sufficiently robust in off-axis collisions and shear loading to be applicable to passenger vehicles. From a clean-sheet approach, lighter structural materials might permit optimization and flexibility in design of “package space” and promote better maneuverability for crash avoidance (through “tunability” of vehicle handling). Such lightweight PCIVs would presumably have a shorter stopping distance as well.

Workshop participants believed that careful application of plastics and composites could enable enhanced crush zone dimensions with minimal impact on interior and exterior dimensions. Robust crush zone behavior is needed for this concept to be viable in production vehicles. Designers particularly cautioned against using high energy absorption components to shrink the crush zone; the effect would be to spike the deceleration forces on the occupant compartment, yielding greater occupant decelerations and increased risk of injury.

Attendees noted the promise of composite parts to promote structural engagement during vehicle-to-vehicle crashes, but these concepts would need to be supported by:

- Parts consolidation
- Mass adjustments
- Flexibility in designing component geometry
- Design to improve energy absorption
- Improved understanding of the effects of process and geometry on performance.

Current Practice for Automotive Materials Selection

It is crucial to understand how new materials and technologies infiltrate a generation of vehicles. Industry representatives discussed the process of materials selection. The key criterion is value, including initial cost, life cycle cost, and profitability in the context of performance. In particular, a material change can occur only if the value or unique capability (e.g., safety benefits) is clear to both producers and customers.

Materials selection is increasingly facilitated by better data on crush characteristics and by evolving modeling tools. Mandatory performance requirements (e.g., new CAFE regulations) hold the promise of encouraging the use of composite materials for both light-weighting and crash strength. The value of durability, longevity and damage tolerance of composites might also spur further material substitution. On the other hand, a potential unintended consequence of improved durability and immunity to corrosion is that it might delay fleet renewal and thus fleet penetration of future safety advances.

The value of a composite system or sub-system must be considered at the vehicle level. The point was made several times at the workshop that feedback loops such as mass compounding (i.e., lighter structure requires smaller engine, etc.) can enable concepts that might appear questionable as isolated material replacements. The ability to optimize a structure early in the design process (in lieu of material replacement in a subcomponent redesign) can radically affect material selection.

Design tradeoffs will come into play in these applications just as in any other. For example, enhanced safety might be enabled at the expense of reparability. Automobile manufacturers must carefully consider how this might affect consumer acceptance. It might be acceptable if the expense of replacement components and their installation could be kept low relative to traditional repair.

Alternatively, OEMs might consider how economical repair of composite components could become a more viable option for PCIVs. Repair education for OEM dealership and independent repair shops would be essential to ensure quality and integrity of the repair. Repair facilities would likely need to be OEM-certified in plastics and composites repair. A partnership might be formed between the plastics industry, automotive experts and the Independent Council for Automotive Repair. Reliable repair cost estimates could be established once repair techniques are developed and quality certified. OEM design optimization and materials characterization are important considerations for cost effectiveness and quality assurance for component repair.

Analytical Techniques for Estimating Crash Safety Performance

The process of developing computational models and comparing them to physical reality is important. The degree of imperfection of a model and the regime over which the model is accurate can eventually lead to understanding of the underlying phenomena. Thus, advances in materials characterization and computational modeling often go hand-in-hand.

The safety analysis of a vehicle depends on the fidelity of several analytical layers. Material models must appropriately capture the behavior of materials (especially deformation and failure) over a wide range of loading environments. Once these models are verified for general material classes, parameters for specific materials must be determined – usually through extensive material testing. These properties may be sensitive to manufacturing processes. Finally, the component geometry and loading details must be understood and modeled. Each of these layers will be important in the design and testing of plastic and composite components expected to see crash loading.

There is concern that not all failure modes and conditions are accurately addressed by current models. The consequence is often that good engineering practice results in costly overdesign. Models can particularly have trouble with the myriad local failure conditions and interactions that are important on the microscale. For example, composites plies with unidirectional fibers can be subject to transverse cracking which can adversely affect strength. A failure criterion developed for and verified with fabric composite structures could therefore significantly overestimate component properties if applied to a structure with unidirectional plies.

Participants were concerned with appropriate materials characterization. Baseline static and dynamic data are needed for all categories of composites in order to evaluate their crash compatibility. Another need is to define appropriate test coupons for different types of composites (e.g., fiber-filled, long vs. short fiber, weave, etc.). Precompetitive cooperation in developing material models and test specimens was deemed preferable. “Round robin” testing and modeling was suggested (e.g., modeling of specific medium-size component, specific loading) to determine the degree of disagreement between different test procedures and models.

It was also noted that material properties determined from coupon tests can be quite different from the in situ values realized in composite components. Processing affects material properties and models often do not reflect these effects adequately.

There was concern regarding the confidence in current computational analyses. Attendees indicated that there is less than 50% confidence in predicted performance of composites, whereas a confidence level of more than 90% is desirable. While steel analysis is typically much greater than 90% accurate and aluminum is about 90% accurate, the commonplace factor-of-two errors with composites often necessitate specialized “development programs.”

At the component level, composite crash predictions can reach 80-90% accuracy. At the vehicle level, it appears that engineering modeling tools are currently inadequate to predict real crash performance for specific materials and designs, while real-world crashes are difficult to control and simulate.

Therefore, one suggestion was to revive the DOE/USCAR Automotive Composites Consortium (ACC) Focal Project 3 (FP3) whole vehicle crash analysis effort. FP3 had been scaled down to component level. Since extreme confidence in crash performance is required to set the signal processing requirements for airbag deployment, the finite element analysis models for multi-materials vehicles must improve considerably. The key questions are:

- How to predict failure in non-homogeneous materials?
- How precise does this failure prediction for a material choice need to be?
- How does the failure impact surrounding material? Is failure propagation consistent in failure mode?

Crash energy management that combines protective designs with advanced structural materials was considered by the SMEs at the workshop to be the key safety research need [4]. Multiple approaches to energy management warrant considerations of multiple materials and material configurations (resin, foam, profiles, etc). The use of plastics and hybrid, sandwich structures that combine metals and composites may be more cost effective than polymeric composites per se.

CONCLUSIONS REGARDING THE PCIV SAFETY RESEARCH STRATEGY

Safety research for future PCIVs must be strategically focused on providing adequate tools and data to the automotive industry. This will allow the industry to confidently design and produce economically viable commercial light and fuel-efficient vehicles with crash safety performance equivalent to or better than today's vehicles. The most basic element of this research will require enhancing the understanding of relevant crash environment material failure mechanisms and their interactions. As these are better understood, standardized test specimens can be developed and material property databases generated. The material models and experimental data must then be integrated into robust analytical capabilities. When these systems approach the accuracy currently enjoyed by those for metals, expensive test and re-design cycles can be eliminated.

The weight and space savings available through part consolidation could be explored as a method to enhance and facilitate the deployment of integrated safety concepts. In particular, the ability to tailor shape and stiffness could be used to "tune" the vehicle's structure and may create sufficiently enhanced maneuverability to optimize some crash avoidance strategies. There could also be efforts to understand the effects of material aging, structural repairs, and of non-crash or post-crash safety issues such as toxicity and flammability. This work could be performed cooperatively, in public-public and public-private partnerships, and be coordinated and integrated with associated topics in manufacturing capabilities, material costs, and sustainability, since the long-term economic viability of PCIV production is as important as enhanced performance.

Several research topics suggested by the SMEs also appear as priority activities identified by the November 2005 ACC-PD workshop [2]. Those selected for the Safety Roadmap development have near-term aspects (e.g., development of improved predictive tools and certified databases on the mechanical properties of advanced automotive composites) that can be continued in the mid-term (e.g., verification and validation of the improved crashworthiness modeling tools). Similarly, the most promising mid-term activities should also have promise and payoffs for long-term PCIV safety technology integration and deployment. For instance, PCIV prototyping and crash testing are needed to demonstrate enhanced protection for all occupants, including the elderly.

NEXT STEPS

Follow-on research partnerships are planned to broaden, deepen, and implement the key near-term PCIV Safety Research Roadmap priorities.

Ongoing NHTSA-sponsored PCIV safety research will focus on the near-term consensus PCIV R&D priorities identified above. PCIV R&D partnership opportunities, that are being currently explored so as to leverage limited resources, include:

- Collaboration with the DOE National Laboratories and DOE/USCAR light-weighting materials crashworthiness and occupant safety consortia;
- Joint funding (with the ACC-Plastics Division and DOE) of Standards Developing Organizations (like the Society of Automotive Engineers), to accelerate the development of testing standards of polymeric composites at high strain rates typical of vehicle crashes;
- Participation in collaborative efforts to update the Composite Materials Handbook (CMH-17) materials testing, database development and modeling tools, specifically its Crashworthiness Working Group (CWG);

- Co-sponsorship of leading academic research Centers of Excellence pursuing research on automotive and aerospace composites.

Further strategies to cost effectively meet the crash safety challenges for lighter vehicles will be considered. The Volpe Center team plans to investigate how overall crash safety in crashes is impacted by structural application of advanced materials for given weight, size and geometry. The team will consider how occupant safety in lighter vehicles can be enhanced by combining crash avoidance systems with advanced occupant restraints.

The approach of this multi-year project and accomplishments to date are intended to facilitate development and deployment of next generation safe and fuel efficient PCIVs by 2020.
This conference offers an opportunity to invite international cooperation on automotive composite materials crashworthiness characterization, quantification, modeling and demonstration [7, 8]. Progress in safety research, technologies and strategies for emerging global platform automotive prototypes of smaller and lighter composite-rich vehicles can inform this project. Inputs from and knowledge sharing with international peers and stakeholders promise to accelerate the resolution of potential PCIV crash safety challenges. International cooperation to quantify the safety of structural composite materials in the early design phases is needed to achieve common goals for crash safety performance and enable early deployment of energy-efficient, sustainable, affordable commercial PCIVs by 2020.

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