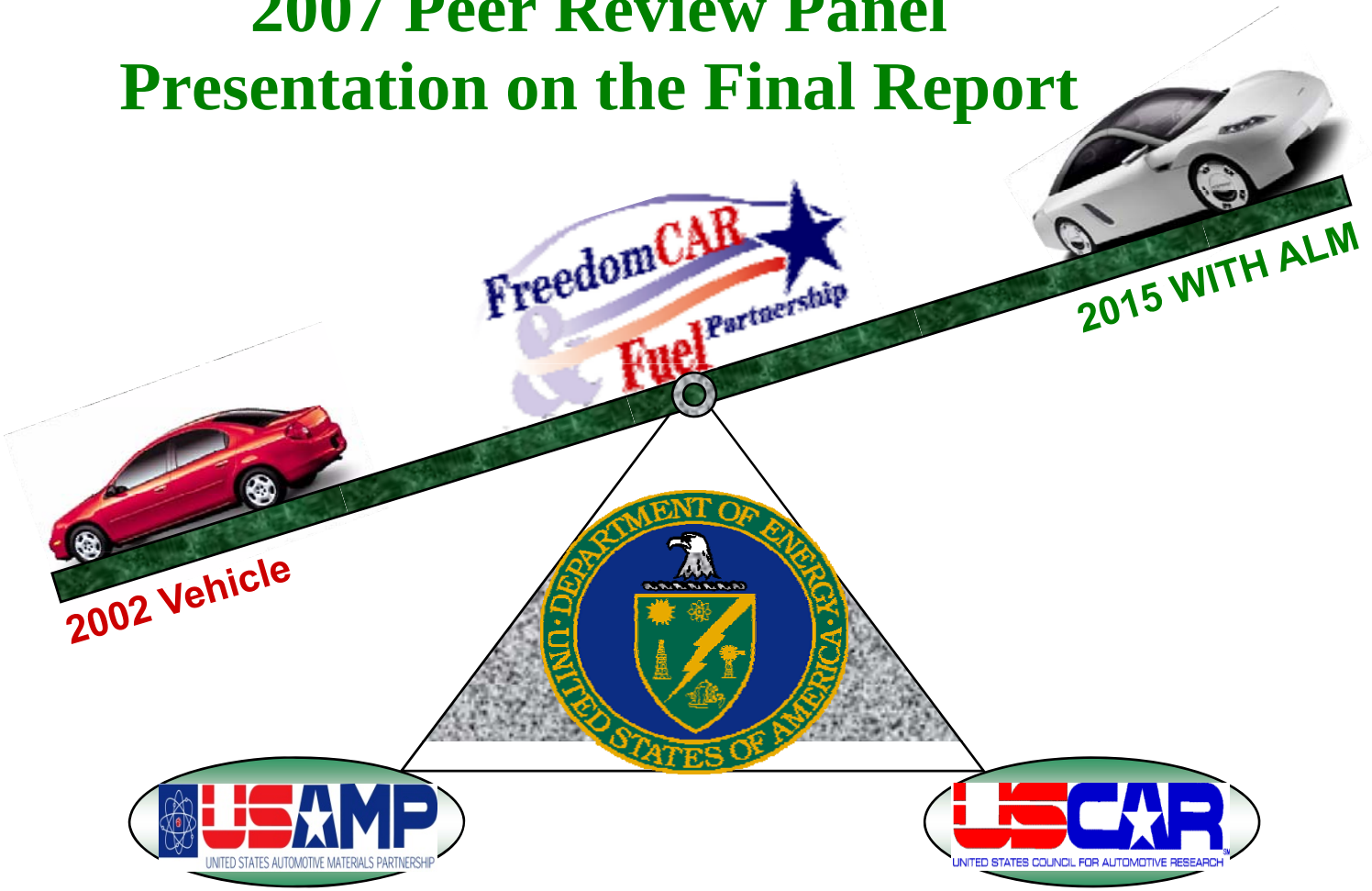
U.S. Department of Energy
Energy Efficiency and Renewable Energy

FreedomCAR & Fuel Partnership

DOE Automotive Lightweighting Materials

2007 Peer Review Panel
Presentation on the Final Report



Presentation Discussion Topics

Introductions/Background – Panel Members, Acknowledgements, Review Mandate, Procedure, Project Judging Criteria and Report Roadmap

- **Five Key Program Level Recommendations**
- **ALM Related Processes**
  - ✓ **Important Findings or Issues, and**
  - ✓ **Topic Level Recommendations**
- **Automotive Lightweighting Materials**
  - ✓ **Important Findings or Issues, and**
  - ✓ **Topic Level Recommendations**
- **Cross Cutting Technologies**
  - ✓ **Topic Level Recommendations**
- **Summary/Takeaway Messages**

Review Panel Members

- **Subi Dinda** – Panel Chair, Senior Manager DaimlerChrysler (retired)
- **John Banisaukas** – Carbon Fiber Composites Industry Expert (retired)
- **Joseph Benedyk** – Research Professor at IIT Chicago
- **Joel Clark** – Professor at MIT (since 1975)
- **Geoff Davies** – Author of Materials for Automobile Bodies & Materials Expert
- **Elio Eusebi** – Head of Polymers Department for GM (retired)
- **Chester Skrzypek** – Senior Manager DaimlerChrysler (retired)
- **Mike Wheeler** – Director of Research Alcan International (retired)

Acknowledgements

- The review panel wishes to acknowledge the support and input from Dr. Joseph Carpenter and his arm's length management position as the panel was deliberating and finalizing this report.

- It also wishes to acknowledge and thank all those from the auto companies and supporting industries, the National Labs and the materials companies, who so willingly shared their time, information and opinions.

- Finally, to thank Don Walkowicz, Executive Director of USCAR, and Kathlene Cook who acted so effectively as our Executive Assistant plus the entire Staff at USCAR, who welcomed the panel to USCAR and provided excellent meeting room facilities, technical support and sustenance.

Review Panel's Mandate

- To evaluate all ALM projects funded by Dr. Carpenter through the FreedomCAR program, and
- To assess how effectively these projects are supporting the program goals of achieving vehicles by 2015 that, when compared with 2002 vehicles, demonstrate the following:
  - ✓ Half the mass
  - ✓ Are as affordable
  - ✓ Have the same performance
  - ✓ Are more recyclable (75% today with aim of 95%)
  - ✓ Are of equal or better quality and durability

Review Procedure

- Panel members attended and participated in the following meetings:
  - ✓ the annual USCAR Offsite meetings where all the current ACC, USAMP and MTT projects were reviewed,
  - ✓ the annual Auto/Steel Partnership DOE Review, and
  - ✓ presentations at the Oak Ridge and Argonne National Labs
- The panel also had access to all completed project reports.
- Experts for the major material suppliers were invited to provide updates on the latest developments in automotive materials.
- Panel members also attended relevant industry conferences during the review period (from Sept 06 to July 07).

Criteria for Judging Projects

- Lightweighting is the fundamental basis for the ALM projects and is applicable to all vehicles no matter the fuel or power system.
- Therefore, each project was evaluated on whether it would:
  - ✓ directly achieve weight saving
  - ✓ enable implementation of other weight saving projects
  - ✓ need development of other new technology to allow implementation
- Recommendations for each major activity were developed based on likely weight savings or the need for implementing technology.

Roadmap for the Peer Review Report

- The report starts with an Executive Summary and Key Recommendations, these being the ones the review panel judged to be critical to the future direction and ultimate success of the ALM projects.
- To facilitate easy access to the report, it is organized with three major sections
  - ✓ Processes,
  - ✓ Materials, and
  - ✓ Cross-cutting Technologies & sub-sections to cover specific topics like:
    - Crashworthiness
    - Corrosion, and
    - Project Management/Development
- Each sub-section has bullet form conclusions and recommendations, and the two most important ones for each topic are gathered near the end of the report into a Summary of Pertinent Recommendations.

Five Key Program Level Recommendations

1. Program management is commendable in the balanced range of activities undertaken and results achieved.

   However, a top-down approach is now necessary to specifically focus portions of the program to achieving the FreedomCAR goals and schedules.

Five Key Program Level Recommendations (Cont.)

2. The FreedomCAR weight and cost targets should be maintained specifically because weight reduction is applicable to all vehicles regardless of fuel/powertrain.

Five Key Program Level Recommendations (Cont.)

3. The portfolio of low-cost carbon fiber projects should be refocused to those that directly support a two year critical path approach for demonstration of commercial viability.

   Further, carbon fiber price vs. usage cost modeling must be undertaken to test whether a $6-$8/lb projected cost would be viable for the FreedomCAR goals.

Five Key Program Level Recommendations (Cont.)

4. The MMV (Multi Materials Vehicle) project should be expanded by engaging an independent design firm to lead development of architecture and material selection to specifically target 50% lightweighting and cost parity targets.

Five Key Program Level Recommendations (Cont.)

5. Five to ten percent of the ALM budget should be allocated to provide seed money for evaluating new and innovative lightweighting projects.

Processes

- Polymer Composites
- Low Cost Carbon Fibers
- Casting
- Powder Metals
- Sheet Metal Forming
- Joining
- Non-Destructive Evaluation
- Recycling Technologies

Topic Level Recommendations

Polymer Composites:

- The Focal Project 4 should continue to be funded as this project has several stretch goals and is an excellent way to bring together various working groups, as well as, to focus and coordinate their activities.

- A project should be initiated to develop nano-composites as matrix materials for fiber reinforced composites. Until now, they have only been used in the automotive industry with thermoplastics and not as a matrix for fiber reinforced composites. Nano-composites could improve the physical properties and also significantly reduce the weight of composite structures.

Important Findings or Issues

Low Cost Carbon Fibers Initiative:

- Automotive CF cost will not be $3-$5/lb, but $6-$8/lb appears possible.
- Actual CF composite costs to auto companies will be higher depending on fiber & composite configurations, i.e., small tow denier, chopped fiber, SMC, filament winding, unitape or woven fabric plus resin impregnation.
- PAN-based PAO & MAP thermal processes represent good bench-scale science, however, they also present major scaling issues/challenges.
- The Lignins approach may ultimately utilize commercially available production volume fiber forming and thermal processing equipment, but precursor purification and fiber spinning must first be demonstrated at least at a lab scale level.

Important Findings or Issues

Low Cost Carbon Fibers Initiative (Cont.):

- To drive the program forward, a formal overall 2 year progress plan, schedule, and key milestones need to be agreed upon and implemented.
- Substantial funding of $6-$8 MM will be required to progress from bench-scale operations to where a pilot line can be adequately designed.
- The need for a low cost T700 12k type CF is not currently being addressed. If this fiber will indeed be necessary in 2015 for filament wound, high pressure, hydrogen fuel tanks, it will have to be purchased from aerospace directed CF producers at perhaps $15-$25/lb.
- Mainstream CF suppliers have little to no interest in supporting the LCCF Initiative - it's simply not in their best interest to do so.

Topic Level Recommendations

Low Cost Carbon Fibers Initiative:

- The ACC should develop an updated automotive grade carbon fiber cost vs. usage model based on a projected CF selling price of $6-$8/lb (2007 dollars) and, according to the new model, determine if continued DOE/ALM funding for the LCCF Initiative is either warranted or acknowledge that, due to projected increases in CF pricing, a program show stopper has been encountered.
- If based on the new CF cost vs. usage model the decision is to go forward with the program, then DOE should continue to fund the ORNL and PNNL LCCF projects to the fullest extent possible, but limit such support to those activities and project milestones identified as being directly on a well defined critical path for expediting LCCF commercialization.

Topic Level Recommendations

Casting Processes:

- The DOE should continue to fund the existing magnesium and aluminum casting projects.

- The recommendations made regarding casting processes within the Magnesium 2020 plan should be adopted provided that impediments challenging their implementation are addressed.

Topic Level Recommendations

Powder Metal Projects:

- The powder metal performance and modeling project should continue, provided substantiated weight savings can be realized.
- The two powder metal projects, AMD 310 and AMD 410 should be combined.
- The USAMP/PNNL initiative to study low cost Ti powder production needs to continually assess the DuPont and ITP process developments, although consideration should be given to transferring the work to the DOE heavy-duty vehicle area.

Topic Level Recommendations

Sheet Metal Forming:

- There has been considerable expenditure on modeling the sheet stamping process to predict and minimize springback. This needs to continue with a new project focusing on specific deliverables and timeline. The problem is most acute with high strength steels but, with the choice of appropriate parameters, the models developed should be applicable to all sheet materials.
- Due to the lack of a clear indicator of formability for the various advanced sheet materials being considered in the FreedomCAR Program, better methods for assessing formability in stamping applications should be pursued. This is particularly important for some of the high strength steels, which only show a conventional elongation of about 5 percent.

Topic Level Recommendations

Joining:

- The present work on spot welding high strength steel and on determining strength and energy absorption of spot welded structures should be continued, but with a narrower focus on the range of steels being evaluated.
- Laser welding should also be added to the spectrum of joining techniques being pursued.
- More investigation needs to be initiated on multi-material joining with the lead for the projects to come from the MMV R&D Initiative, and this should include evaluating the techniques and experience developed in Europe for multi-material joining.

Topic Level Recommendations

Non-Destructive Evaluation:

- NDE work on spot welding with emphasis on high strength steels should be continued, including developing means for identifying welds that will exhibit interfacial failure.
- NDE techniques should be focused on appraising the structural integrity of both original and post impact composite materials, and
- NDE activities for adhesive bonding should be expanded.

Topic Level Recommendations

Recycling Technologies:

- Projects to develop and demonstrate technology to enable recycling of future automotive materials should be continued.
- Cost models of the recycling processes need to evolve in order to determine what needs to happen before processes can be commercially competitive.

Materials

- Aluminum
- Magnesium
- Steel
- Metal Matrix and Titanium
- Multi Materials Vehicle

Important Findings or Issues

Aluminum:

- The cost delta of using aluminum in an Al intensive vehicle can be as low as $100, given the secondary weight and cost savings stemming from the primary weight saving. The lifetime savings can be 10X this.
- The use of aluminum is growing in the worldwide auto industry including for both safety critical and skin panel applications.
- New processes are emerging for manufacturing aluminum products and specifically ablation casting for producing high quality low volume parts and as prototypes for high volume PM structural castings and Fusion casting for enhanced performance sheet products.

Topic Level Recommendations

Aluminum:

- The aluminum industry should be encouraged to become re-engaged with the ALM, and particularly through the MMV R&D Initiative.
- The ablation casting project should be continued as it has the potential to provide high quality components both for low volume applications and as prototypes for high volume structural castings.
- The opportunities for improved sheet products that could come from the Fusion Casting process should also be explored.

Important Findings or Issues

Magnesium:

- Due to the importance of China in controlling magnesium supply, economic analysis of projected cost scenarios should be done taking into account the conditions surrounding currency revaluation and technical developments taking place in China.

- The USAMP magnesium projects already completed have been successful in prompting the expanded usage of magnesium in lightweighting U.S. automotive industry vehicles.

- With the investment made by the Chinese in magnesium technology, they are set to dominate the future market not only in primary magnesium but undoubtedly in the supply of downstream wrought and cast products.

Topic Level Recommendations

Magnesium:

- As magnesium offers so many lightweighting alternatives in automotive applications and has shown so much promise in completed USAMP projects, all the proposed USAMP magnesium projects should be fully funded as presently planned.
- The three country collaboration of the USA, Canada, and China in the magnesium front-end project should be maintained as a means for reducing the cost of this development project and for tapping into the best technologies available.
- The AMD should review the need to explore clean and energy efficient magnesium production in the states.

Topic Level Recommendations

Steel:

- The $2MM/yr DOE funding should be continued on steel programs, which are already playing a significant role in accelerating the development of new applications for advanced high strength steel with regard to lightweighting both structural and closure panels.
- The program initiated by DOE with NSF and A/SP for the development of a third generation of advanced high strength steel in collaboration with academia, the steel industry, and auto industry should be encouraged and continued.
- A coherent structure must now be agreed upon for future programs.

Topic Level Recommendations

Metal Matrix Materials and Titanium:

- Continued funding of low cost titanium is recommended unless this is in conflict with higher priority projects, and consideration should be given to transferring the work to the DOE heavy-duty vehicle area.

- Continued metal matrix project activity is not recommended unless risk factors are minimized.

Important Findings or Issues

Multi Materials Vehicle R&D Initiative:

- This initiative must be regarded as a key driver for ALM in order to focus new and ongoing projects to the development of technologies for mixed-material, concept vehicle body-structures that approach the FreedomCAR goals.

- The Initiative is in the early$_{sta}$ ge of development and needs to be widened to explore what is possible with a true mix of materials rather than the very limited mix in the present project.

Topic Level Recommendations

Multi Materials Vehicle R&D Initiative:

- Technology gaps identified through the MMV R&D Initiative should be evaluated as input for new project selection for support by the ALM portion of the FreedomCAR program.
- Projected weight and costs for virtual full body structures should be developed for a variety of multi-material vehicle structures including aluminum and carbon fiber composites in addition to the materials already included in the MMV R&D Initiative.
- Consideration should be given to having an independent design firm lead a multi-material vehicle structure design project utilizing various materials to minimize weight and cost.

Cross Cutting Technologies

- Cost Modeling
- Crashworthiness
- Corrosion
- Project Management/Development

Topic Level Recommendations

Cost Modeling:

- Technical cost models are useful and should be used where commercial feasibility is an issue and when costs for alternative designs or manufacturing process and/or materials need to be compared.
- Cost models can and should be used when it is necessary to know "what needs to happen" for cost targets to be achieved.

Crashworthiness:

- Joining technology for individual components should be explored to determine its contribution to crash energy absorption, especially in the hybrid structures of the MMV project.

Topic Level Recommendations

Corrosion:

- The project to develop a reliable accelerated corrosion test for aluminum closure panels should be completed and published as an SAE method.
- The cooperation with CANMET MTL to develop corrosion protection methods for magnesium components should be continued, and there should be some cross ties to the mixed material joining projects as these could mitigate or indeed solve some of the corrosion problems arising from assembling multi material structures.

Topic Level Recommendations

Project Management/Development:

- The overall management of the ALM FreedomCAR portfolio of technical projects is commendable.
- Oversight of the entire portfolio is critical to the success of this effort, and a top-down approach is now recommended for key projects in order to drive the program towards achieving the FreedomCAR goals and schedules.
- Five to ten percent of the materials budget should be devoted to funding new and innovative projects aimed at meeting the FreedomCAR goals.

Summary/Takeaway Messages:

- A top-down program management approach is now necessary to specifically focus portions of the program.
- The FreedomCAR weight and cost targets should be maintained.
- Low-cost carbon fiber projects should be refocused and a cost model must be undertaken based on a $6-$8/lb. CF selling price.
- The Multi Materials Vehicle project should engage a design firm to lead development of architecture and ma terial selection to target 50% lightweighting and cost parity targets.
- 5-10% of the ALM budget should be allocated to provide seed money for evaluating new and innovative lightweighting projects.

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Thanks for Your Attention

That Wraps Up Our Presentation

Any Questions or Comments?

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PC1 John Banisaukas, 7/25/2007