CARS Annual Report 2011
Center for Automotive Research at Stanford

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1 Summary

Over the year 2011, Stanford University’s automotive affiliates program, CARS, explored research topics in four main areas: Driver Assistance, Alternative Energy, Connected Mobility, and Mobile Society. A broad variety of workshops, lectures, and community events were organized in those areas gathering the automotive community of students, researchers, and industry at Stanford.

Those events also documented that CARS, in the third year of its existence, has established a vibrant on- and off-campus network that is dedicated to the future of the automobile. Through those activities and with the help of that network, CARS has become an important hub to initiate automotive research and education programs at Stanford. The Revs Program at Stanford, the fellowship program “Legal Aspects of Autonomous Driving”, and independent studies in fields such as “Electric Mobility” or “Carsharing” are some of the 2011 examples where CARS has helped to establish new activities, while some of those later continued as self-sustained programs. CARS is also proud to count twice as many affiliates at the end of the year and to have introduced a tiered membership model that better addresses different interests of current and future affiliates.

Looking forward, CARS will seek additional partnerships with IT and startup companies to complement the profound automotive background of the program. It will also further support activities in “wireless charging of electric vehicles” and “safety relevant vehicle communication via cellular technology” to advance research in those fields. The classes that CARS is organizing, such as “The Future of the Automobile” or “Electric Vehicle Design” will be offered again, while community events and special lectures will complement the schedule for 2012.

2 CARS Community and Network

2.1 Stanford Partners

After three years in operation, the Center for Automotive Research at Stanford is now well established in Stanford’s academic community of labs, classes, and programs. It can be claimed that CARS and the Volkswagen Automotive Innovation Lab (VAIL) are being recognized as a hub for automotive topics at Stanford, if not in Silicon Valley in general. The program is receiving many requests to host events, present at symposia, and initiate research and education programs. Through those activities, CARS maintains strong relationships, primarily within its organizational home, the School of Engineering, but also the Law School, Graduate School of Business, and Precourt Energy Efficiency Center.

This on-campus network, which has a very strong interdisciplinary character, presents a very fruitful platform to launch programs in “Autonomous Driving”, “Connected Mobility”,

CARS on-campus network, primary partners
“Electric Mobility”, and others that will be discussed in the respective paragraphs. Those new programs and initiatives also emphasize the growing automotive interest on campus. As a quantitative measure, the on-campus network is characterized by two core faculty, Prof. Chris Gerdes and Prof. Cliff Nass, and about 30 faculty / researchers that interact with CARS on a regular basis in very diverse aspects pertaining to the future of the automobile.

2.2 Industry Affiliates

Since the last CARS Annual Report was published in December 2011, the affiliates program has grown substantially. Volvo Cars, Hyundai, BMW, Ford, Chrysler, and Renault have joined the community. While this presents a growth of more than 100% in 12 months (Nov 2010 – Nov 2011), the program is committed to maintain personal relationships with its affiliates and to establish close connections among academic and industry partners as the basis for a strong community.

Feedback from the industry affiliates shows that the personal character of the program and the structured as well as regular information updates (see 3.4.2) are very well suited to support the industry partners with their ventures on campus.

For the future, CARS would like to seek additional affiliates in the IT industry, such as internet, computer, and communication companies with interest in the fields of driver assistance, connected mobility, and mobility services. With the already very well established network and partnerships, growth in that direction is well conceivable.

2.3 Extended Community and Public Communication

2.3.1 Extended Network

Besides its formal industry affiliates and the on-campus partners, CARS also maintains vital relationships with many other corporations and research institutions. The CARS workshops, expert discussions, and community events that were held during the year document that external network. Many Silicon Valley companies and organizations are being tied into those events on a case-by-case basis, such as AT&T, Cisco, General Motors, Intel, Oracle, NASA, UC Berkeley, Santa Clara University, and many others. It is hoped that some of those connections can also be turned into more formal relationships in the near term.

2.3.2 Public Communication, Media

Over the year, CARS received many requests from local, national, and international media for interviews, visits, and video documentaries. One of the most publicized events was a visit from CBS Smart Planet to feature the different projects in Stanford's automotive lab. The online documentary featured the work from the Dynamic Design Lab, Autonomous Driving Group, and Solar Car Project. A special focus was put on the autonomous driving group in the CS department, which researches computer vision, sensor fusion, and probabilistic planning in the automotive context.
Other media events include phone interviews and on-site visits. Most requests centered on research in autonomous driving, electric vehicles, and connected mobility. Beyond media coverage, these requests included speaking engagements, both documenting that CARS is recognized as a source for information and thought leader in those fields. Thereby it can be claimed that the on-campus research and the broad industry support that make up the automotive community on campus have been instrumental in establishing Stanford University as a significant location in the international automotive landscape.

3 CARS Activities and Events

3.1 Research Initiation

While CARS, true to its status as an industry affiliates program, does not fund research projects directly, it is instrumental in initiating research activities, which are independently run within labs or research groups after a certain incubation period. In doing so, CARS pursues four main directions that are crucial to the future of the automobile and personal mobility: Driver Assistance, Alternative Energy, Connected Mobility, and Mobile Society. The following paragraphs give an overview of the different research programs that CARS helped to get started in the past year.

3.1.1 Revs Program

The Revs Program at Stanford was established in fall 2010 and had its inaugural event in April 2011. Its goal is to inspire a new trans-disciplinary field connecting the past, present and future of the automobile. The program fosters an intellectual community bridging the humanities, fine arts, social sciences, design, science and engineering, and the professions. It focuses on the human experiences of designing, restoring, driving, and dreaming of the automobile, as well as the automobile itself as machine, work of art, and cultural symbol.

CARS helped to setup the initial structure of the Revs Program and also to establish a network of supporters and collaborators on- and off-campus. Part of that help was the shared use of resources between the two programs and hosting events together.

During the year, the Revs Program participated in various events of historic vehicle racing and connoisseurship, such as the Monterey Motorsports Reunion and Porsche Rennsport Reunion. It also launched numerous research activities that contribute to what is called “Auto-Biography of a Car”, an interdisciplinary study of a specific automobile to better understand the driving experience and its interdependencies with engineering / design as well as culture / society.
3.1.2 Fellowship Program “Legal Aspects of Autonomous Driving”

The collaboration between the Stanford Law School Center for Internet and Society (CIS) and CARS gave birth to the fellowship program “Legal Aspects of Autonomous Driving”, which was launched with the new academic year in September 2011. The goal of the program, which is supported by a group of 5 CARS industry affiliates, is to help pave the way toward safe and efficient autonomous driving through close study of the engineering, legal, and policy hurdles.

The program consists of a research fellow, Bryant Walker Smith, with an interdisciplinary background and an advisory board of industry partners, practicing lawyers, and academic mentors. The program pursues the following publications for the first two years:

- Database of relevant legal and engineering developments to provide essential information on the topic of autonomous driving to academia, industry, government;
- Report to Congress and other policy-makers to address necessary actions;
- Communications strategy to educate the public about autonomous driving;
- Landmark conference to initiate a dialogue between engineering and legal experts.

The program coincidently started around the same time when the State of Nevada initiated its legislative process to regulate the testing and operation of autonomous vehicles. Therefore the program could seize the opportunity to be instrumental in connecting state officials, industry, and academia in the rule-making process. For the next year, the program plans to establish an overview of the general legal situation for autonomous vehicles in the country and to prepare recommendations for policy makers and industry.

3.1.3 Simulation Study “Wireless Charging for Electric Vehicles”

In 2009, CARS joined forces with Stanford's Global Climate and Energy Project (GCEP) to advance research in electric mobility and address the issue of the limited range of electric vehicles. As a unique approach, it was proposed to combine elements of wireless power transfer to the moving vehicle and automated vehicle control to maximize the range, energy efficiency, and convenience of such travel. The concept was originally termed "Unlimited Range Electric Mobility - UREM" and has since been studied in an initial simulation project to investigate if such electric power transfer can meet the base power consumption requirements of a vehicle while traveling at highway speed (i.e. transfer of 20kW over a range of 1m at 65mph).

Prof. Shanhui Fan and Xiaofang Yu in the Electrical Engineering Department conducted the simulation study with funding from GCEP. The initial results show that power transfer is possible with an efficiency of greater than 97% over a maximum range of 2.0m. In the fall of 2011, a patent application entitled "Wireless energy transfer with the presence of metal planes" was filed by the researchers, which essentially seeks to protect the intellectual property of the magnetic coil design that enables the high-efficiency transfer.
of power over this relatively long distance. For the year 2012, the researchers have solicited additional funding from GCEP to investigate the safety aspects associated with the power losses that take place at the levels of power transfer needed for automotive applications with the proposed coil design.

The long-term plan for this project envisions conducting a small-scale hardware demonstration leading eventually to the construction of a full-scale test track and vehicle. In order to accomplish this vision, GCEP and CARS sought additional partners at the Precourt Energy Efficiency Center and in the Department of Civil Engineering at Stanford who will begin performing an overall systems assessment of the concept and will investigate roadside infrastructure implementation. With these partners, it is expected that over the year 2012, a much more holistic understanding of the overall concept of wireless power transfer, automated vehicle control, and data communication will be achieved.

### 3.1.4 Connected Mobility

Following a CARS workshop in November 2010, when only a very small overlap of academic and industry interest in research directions toward connected vehicles and in-car online services could be identified, the affiliates discussed potential research fields in more detail. At an expert roundtable meeting in October 2011 a strong interest in solutions for safety relevant vehicle communication over cellular communication networks was formulated. CARS has since been working with faculty and students on a research proposal to investigate alternatives to DSRC (Dedicated Short Range Communication, i.e. the U.S. DOT lead vehicle-to-vehicle and vehicle-to-infrastructure communication program that is not expected to become available in the near-term). While an outlook at this proposal will be given at the CARS Annual Meeting on Dec 1, it is aimed to initiate further research in the first quarter of 2012, if academic and industry support can be aligned to support that topic.

### 3.1.5 Electric Mobility

The field of electric mobility has been researched in many different groups at Stanford for some time, such as the Precourt Energy Efficiency Center, the Graduate School of Business, the Communication Department, the Material Science Department and others. CARS has helped to connect those activities and forge a more closely connected community.

Instrumental to combining those independent research directions was the Sustainable Transportation Seminar that was established together with Precourt researchers in spring 2011 (see 3.3.1). The regular exchange with this group also lead to the CARS Electric Mobility Workshop in May (see 3.3.1), when directions for initial studies were discussed and later conducted as part of the independent studies to better understand and connect consumer considerations, battery technology, and lifecycle assessments.
regarding electric vehicles (see 3.2.4). Beyond the independent studies in fall, specific aspects of the initial stage might be continued depending on the academic and industry interest, while it could also be considered to use the results as a basis for research in the field of consumer behavior and product requirements in the context of increasingly electrified vehicles.

Besides the collaboration with on-campus partners, CARS has also helped its industry affiliates to evaluate research opportunities in the field of electric mobility. As a consequence, Stanford will have a small electric vehicle fleet as of 2012 to research the range limitation of electric vehicles and how consumers deal with this restriction as well as which concepts can help to overcome respective consumer concerns. In addition, simulator studies are being performed to educate drivers regarding more efficient driving patterns.

3.2 Student Interaction: Classes, Projects, Recruiting

3.2.1 Interdisciplinary Class “The Future of the Automobile”

In the winter quarter, CARS organized its regular seminar class "The Future of the Automobile" to follow the theme "Electric Mobility - What is Missing?". The course addressed the question why there seems to be disconnect between what consumers think about the future of mobility and how they make their vehicle choice. CARS affiliates and other industry partners participated in that class as presenters and in the audience. Guest lectures from industry and academic experts approached the theme from different angles such as technology, business, environment, society, and policies. Students were asked to draft one-page essays on specific problem statements in that context, such as what it would take to help electric vehicles become a market success. Those essays were also used as input to the workshop in May and independent study in fall.

In the spring quarter the class "The Future of the Automobile" was following the theme "Intelligent Vehicles - How Smart Can They Get?". The course was divided in one half that focused on "Advanced Driver Assistance Systems" and instructed by Dr. Jan Becker of Bosch, and the other half focusing on "Vehicle Safety Communication", which was instructed by Dr. Luca Delgrossi of Mercedes-Benz. The schedule for the seminar class comprised a mix of lectures by those industry experts and open discussion sessions. During that quarter, class enrollment numbers reached its all-time high with 60 students from engineering, business, law, and other disciplines. That proved the strong interest among Stanford students in automotive topics and that the seminar class "The Future of the Automobile" is an effective way to connect with students to establish connections for future careers.
3.2.2 Electric Vehicle Design Class

Also in the spring quarter, CARS organized a project class titled “Electric Vehicle Design”. The project based class focused on the design and prototyping of electric vehicles. Students learned the fundamentals of vehicle design in class and applied the knowledge as they formed teams to work on projects involving concept, specifications, structure, systems, integration, assembly, and testing of their ideas. Over the course of the quarter, students worked in groups of 3 or 4 on electric bicycles, micro commuter vehicle, electric racing kart, and electric power train components that were also used for the Stanford Solar Car (see 3.2.8).

At the end of the quarter the students presented their concepts as part of the Stanford annual design fair “EXPE”. An additional presentation the same day was the community event with CARS affiliates and the extended network to discuss the student projects and connect students, researchers, and industry.

3.2.3 Business School Class “Industry Strategies for 2020”

In the autumn quarter, CARS worked with Prof. Robert Burgelman at the Stanford Graduate School of Business to teach a seminar that looked at the evolving global automotive industry with a special focus on the year 2020. The conceptual framework of the class included tools of strategic and competitive analysis to understand the role of strategy making in the evolution and transformation of organizations, industries and societies. With the focus on the automotive industry the class was structured on the one hand by different regions, i.e. United States, Europe, Japan / Korea, and China. On the other hand the class entertained the four main directions that are crucial to the future of the automobile and personal mobility: Driver Assistance, Alternative Energy, Connected Mobility, and Mobile Society (see also 3.1). Guest lectures provided input from the different regions and directions as industry experts from General Motors, BYD, Hyundai, and Volvo Cars presented their corporations and industry trends to the students.

As a result for the strategy class, three student teams composed term papers on one region and direction of their choice. One team looked at the United States asking the question why and / or to what extent OEMs should get invested in the development of electric vehicles. In order to structure that field, it was assessed if “the bare minimum”, “middle-ground”, or “entire fleet electrification” approach would be recommended. Another team examined the situation in Europe, and to what extent a premium product strategy is advisable to stay competitive in a global market that might move toward a commoditization of the mobility sector. Their term paper analyzed the potential for a carsharing program of performance vehicles that would also provide a social / business networking component. The third team looked at China, discussing which strategic considerations need to be made for new entrants into the automotive industry, especially in the electric vehicle space. Their paper discussed that the electric vehicle market is expected to be small in China compared to the U.S., and therefore trade taxes need to be considered very carefully if a Chinese company wants to get invested in that field.
3.2.4 Independent Study “Electric Mobility”

Based on the outline that resulted from the CARS workshop in May (see 3.3.1), a team of 4 students investigated the respective fields “Consumers”, “Technology”, and “Impact” of electric mobility as an independent study topic. The group, along with support from the Precourt Energy Institute, structured the field in four sub-topics, so that one part of the study considers the consumer purchase decision regarding “green” products in general and electric vehicles in specific. While a large diversity of publications and material was reviewed, consumer motivations for or against certain vehicle types were discussed, as well as expectations regarding vehicle performance, range, and style. Another direction for the study was looking at different battery technologies with a specific focus on potential breakthroughs in that field. These would be metal-air, as well as semi-solid and solid-state batteries. An overview was created to compare those solutions and summarize forecasts for future product applications.

In order to better understand the environmental impact of the vehicle electrification, another part of the study compared different lifecycle assessments (LCA’s) and discussed how beneficial different levels of vehicle electrification would be in that regard. The comparison also gave insight to different sources of information and compared which assumptions are being made for the assessment. As a summarizing component in the study, a vehicle concept recommendation was made as to how much electrification is ecologically, technically, and economically sensible. Therefore, the input from the consumer aspects, battery technology, and life cycle assessment were taken together and applied to discuss the different vehicle concepts such as HEV, PHEV, REV, BEV.

At the end of the study it was recommended that more research should be conducted to determine how much electrification (i.e. hybrid, range-extended battery, or battery only electric vehicle) presents the most sustainable solution for personal mobility. This got especially clear as it was found that the stated and revealed preferences of consumers regarding an “environmentally friendly” product could differ substantially, so that the purchase decision would be difficult to predict and direct. Parts of these aspects were directly proposed for follow-up studies and PhD research.

3.2.5 Independent Study “Risk Assessment of Autonomous Driving”

At the January 2011 workshop (see 3.3.1) the CARS affiliates discussed failure modes and risk analysis for autonomous driving and crafted a problem statement that lead to an assignment for an independent study project in autumn quarter. It was asked how functional safety requirements for autonomous vehicles could be established for such technology ahead of its deployment to the market. Therefore, a critical initial exploration was proposed to frame the topic and investigate basic considerations:

- Definition of typical operating situations relevant for the safety of autonomous vehicles
- Classification of these situations regarding their likelihood, severity, and controllability
- Recommendation of general rationale for remedial actions in case of system failure

A group of two students supported by Stanford researchers started by defining 5 situations that would help with the assessment of the potential risk if the autonomous
driving mode needs to be suspended during those situations: maneuvering into parking spot, approaching a busy cross-walk, highway merging, general highway driving, passing on an undivided highway. Additionally, failure modes were defined in terms of different functionalities that can fail (e.g. longitudinal control, lateral control, velocity / heading determination, positioning system, object recognition) and which incidents might lead to failure. In a next step the likelihood, severity, and controllability of those situations and failures were being estimated to assess the risk. While the overall assessment for the entire driving process was deemed to be much too diverse and complex to be considered for a one-quarter study, the work of the students yielded recommendations for a comprehensive risk assessment that would need to be conducted based on this initial study.

The study also included recommendations regarding additional safety features for autonomous vehicles that would be deployed in case of severe system failure. Those could be additional warning instruments or vehicle-to-vehicle communication, which was proposed as an important part to ensure safety of autonomous vehicles in those emergency situations.

3.2.6 Independent Study “Peer-to-Peer Carsharing”

An independent study by one individual student generated an overview of peer-to-peer (p2p) carsharing in terms of current situations and future trends. Well more than 20 offers for p2p carsharing could be identified worldwide, with a summary and comparison being part of the final paper. Interviews were conducted with some of the carsharing companies (Zipcar, Wheelz, HiGear, and others), which gave insights into the different business models and customer groups. As a result of the study, it was pointed out how important a seamless technology concept is to facilitate the sharing experience and which new business models might evolve around the idea of sharing vehicles between individuals and / or individuals and commercial providers.

The study suggested that peer-to-peer carsharing might be in the end just the first step of a transition toward a society and lifestyle where more and more goods are being shared and rented as opposed to be owned. The current trend might be seen as a movement to break up some of the existing structures and ownership models and that vehicle sharing might evolve into a yet to be defined fusion of public-personal mobility. The study also confirmed carsharing in general as a long-term trend, which magnitude is still difficult to predict, but that car manufacturers see it as a considerable impact to their business.

3.2.7 Other Class Involvement

In the spring quarter the class "Creativity & Innovation", which was supported by CARS, chose a project to create a vision for the future driving experience. 40 students worked in 10 teams to innovate concepts that address the needs and challenges of drivers. Students conducted an interactive interview process with different individuals, including several CARS affiliates, to gather an overview of what different individuals like or dislike about driving an automobile. The results and ideas for concepts were presented as brief video clips and discussed in class when the affiliates were invited again. The concepts ranged from games to make driving more social to solutions for a more efficient and safer commute.
Another teaching activity that CARS became involved in was the “Forecasting for Innovators” class that is co-instructed by Consulting Associate Professor and Forecaster Paul Saffo. In that class, the students were asked to create scenarios as to when certain technologies would play out in the market place. Upon suggestion by the instructors, CARS introduced autonomous driving as a technology that should be looked at regarding a deployment forecast. Interestingly enough, the students decided despite high initial interest, that the technology would be too predictable and therefore did not pursue that topic. However, as the forecasting methodology of the class would be very interesting to apply to mobility related topics, another automotive theme might be proposed for the next term in 2012.

3.2.8 Solar Car Project

In 2011, the Stanford Solar Car Project, which is also a strong member of the CARS community, competed in the World Solar Challenge, the race from Darwin to Adelaide. Despite having its home base in the CARS operated Volkswagen Automotive Innovation Lab (VAIL), the largely self-organized undergraduate team also benefits from CARS’ administrative support for their equipment, logistics, purchases, and funding.

In August, after well more than one year of work, the Stanford Solar Car Project officially unveiled their entry for the 2011 World Solar Challenge at VAIL. The completely new-designed vehicle called “Xenith” boasted of several industry-leading technological innovations such as extremely low aerodynamic drag, high efficiency motor, low-reflective solar arrays, heads-up display, telemetry and rear wheel steering to compensate for cross wind and improve maneuverability. Equipped with those features, the team was confident to be very competitive for the 2,000mls race across the Australian outback and beat its main competitor from the University of Michigan. However the conditions during the race in October were not in favor of the Stanford team with high winds, bush fires, persistent high altitude clouds, and considerable amounts of rain. In the end the Stanford team finished on 12th rank out of 37 teams, which was still a very good result given some major mechanical failures that were encountered during the race.

3.2.9 Resume Book and Student Recruiting

In February CARS offered its affiliates for the first time a resume book that was compiled of resumes from undergraduate and graduate students with automotive interest in internships or career starter positions. About 50 candidates were listed in a searchable spreadsheet with the student's summary data and the resumes linked in as PDF documents. CARS also offered its affiliates additional assistance to contact students for further consideration.

The resume book was well received by the affiliates and will be offered again in 2012. During the year, CARS assisted its affiliates in their recruiting efforts on campus by
facilitating attendance at career fairs and sending out job opportunities via the extensive CARS mailing list.

3.3 Workshops, Expert Meetings, Community Events

3.3.1 Workshops and Expert Discussions

During the year 2011, CARS hosted several workshops and expert discussions. In these events, the affiliates discussed directions for technical studies or more detailed research. In January a workshop with the title "Risk Assessment & Failure Modes for Autonomous Vehicles" was organized with industry partners and Stanford researchers to discuss failure situations of autonomous driving. The exchange highlighted the importance of commonly shared safety standards and procedures for autonomous vehicles. As a result from the one-day event, which took place in Michigan to distribute the travel efforts among affiliates more evenly, a problem statement was drafted that eventually was used as input for the independent study “Risk Assessment of Autonomous Driving” during the autumn quarter (see 3.2.5).

With the beginning spring quarter in April, CARS and the Precourt Energy Efficiency Center launched the Sustainable Transportation Seminar that brings a wide range of faculty, students, and industry experts together to discuss topics at the intersection of transportation, energy, and environment. The weekly meetings are held as informal presentations with open discussion sessions and are also attended by CARS affiliates as topics range from passenger vehicles, to high-speed rail, to general transportation studies.

In May an Electric Mobility Workshop was hosted to pursue the objective of setting the scope for a study on the connections and interdependencies of technology, business, and environment pertaining to electric vehicles. Domain experts from the CARS lecture series in winter (see 3.2.1) presented their talks on battery, business, lifecycle, and strategy considerations again. The first day concluded with an informal fireside chat with the opportunity for more specific discussion on the respective subjects and to connect more with the domain experts. On the second day, the affiliates discussed aspects that require further consideration to understand and manage the transition toward an increasingly electrified mobility sector. At the end of the second day, a problem statement was drafted that highlighted the need for studies in the fields "Technology", "Consumers", and "Impact". This problem statement was subsequently used as input for an independent study in the autumn quarter to investigate those different fields and their interdependencies (see 3.2.4).

In October, CARS hosted an expert discussion on connected mobility. The objective of the roundtable event was to bring academia and industry together and discuss expectations, challenges, and solutions for wireless communication with vehicles. Therefore three directions were proposed for the discussion to identify research topics that would enable reliable and enjoyable communication applications for vehicles. Those directions were the general compatibility of cellphone networks with mobility requirements, future trends in wireless communication, and the possibility to use cellphone technology for vehicle-to-vehicle communication. The 2-hour moderated discussion was attended by about 20 industry experts and Stanford faculty / researchers and focused heavily around opportunities to use cellular communication for safety and efficiency improvements in traffic. While it was agreed that the U.S. DOT led DSRC
approach would be extremely beneficial, it was also concluded that the deployment would take still more than a decade so that alternatives with existing infrastructure should be considered until then. Therefore CARS proposed to discuss this topic further with Stanford researchers and identify potential research directions (see 0).

For December, a workshop was proposed to discuss the findings from the independent studies (see 3.2.3 - 3.2.6) in conjunction with the CARS Annual Meeting. At the time when this document was written, the plan was to have student presentations from each of the study fields (industry strategies for 2020, electric mobility, risk assessment for autonomous driving, and peer-to-peer carsharing) followed by an informal lunch gathering for additional discussion and exchange.

### 3.3.2 Special Lectures

Besides the regular seminar, “The Future of the Automobile”, CARS was also hosting special lectures that were typically attended by a broader community. Industry experts presented their projects and visions for safer and more efficient mobility, which was usually followed by a networking reception to connect with experts and enthusiasts.

In May, CARS and the Precourt Energy Efficiency Center hosted a special lecture by Byron Shaw, Managing Director of the General Motors Silicon Valley Office, as part of the Sustainable Transportation Seminar. In his talk, which was titled "Sustainable Transportation at GM: Volt, EN-V, and Beyond", Byron Shaw discussed the approach that GM is pursuing for vehicle electrification, which is the range-extended battery electric vehicle, recently released with the Chevrolet Volt. As the future vision, he explained the EN-V (electric, networked vehicle), which was also one of the automotive highlights at the 2010 World Expo in Shanghai. After the presentation, which was attended by more than 100 people from academia and industry, the EN-V concept vehicle was available for driving demos outside the Volkswagen Automotive Innovation Lab (VAIL).

In June, Erik Coelingh, Project Leader for the SARTRE Road Train Project at Volvo Cars, gave a special lecture on this project that aims to platoon vehicles for increased safety and efficiency. He discussed platooning strategies consisting of a lead vehicle driven by a professional operator and followed by other vehicles autonomously. He explained how this concept would allow those road trains to operate on public highways without changes to roadside infrastructure. The presentation was followed by an open discussion with the CARS community that touched also on many non-technical issues such as legal aspects and human factors of automated / autonomous driving.

In August, CARS and the Revs Program organized a special lecture titled “A 21st-Century Approach to Car Design and Manufacturing” by Gordon Murray, Race Car Designer, Engineering Professor, and Entrepreneur. Best known for his design of Formula 1 vehicles and production super-cars, Gordon Murray introduced his latest venture, which strives to develop extremely lightweight and economical city cars such as the T.25 and T.27. He discussed in his talk those recent
prototypes that rely on the iStream concept with lightweight frame and composite panels. The lecture, which was attended by about 180 people from academia and industry, was followed by a networking reception and CARS affiliates were also given the opportunity to have one-on-one meetings with Gordon Murray to discuss further details of his concepts and ideas.

In October, David Wagner, Project Manager with the Lightweight Vehicle Team at Ford Motor Company, gave a special lecture on "Lightweight Automotive Structures". In his talk he discussed the current and future role that advanced high strength steel, aluminum, magnesium and composites can have in lightweight automotive structures. He also highlighted challenges regarding material performance, part production times, and assembly issues and overall system costs. Many experts from the energy efficiency, material science, and vehicle concepts fields attended the event, which resulted in a very much appreciated and informative discussion after the talk.

In November, Patrick Stenner, Research Associate at the Institute of Automotive Technology of the Technical University of Munich / Germany, gave a special lecture to introduce the university’s MUTE vehicle project. He explained the highly efficient vehicle concept that keeps power consumption to a minimum thanks to its lightweight design, optimized aerodynamics and energy-efficient components. CARS and the Precourt Energy Efficiency Center jointly hosted the talk as part of the Sustainable Transportation Seminar, which gathers experts from academia and industry to discuss mobility options for the future.

3.3.3 Community Events

In addition to the special lectures, CARS also hosted community events, which typically gathered a broad community of people from academia and industry sharing a common interest in the theme of the respective event. For those events the Volkswagen Automotive Innovation Lab (VAIL) presents an optimal setting as it offers space for very large groups and the opportunity to have vehicles inside or outside the event venue.

In April, the Center for Internet and Society (CIS) at the Stanford Law School and the CARS affiliate Robert Bosch LLC hosted the Robot Block Party as part of the National Robotics Week, which drew about 1,000 people in one afternoon to VAIL. At the event, 15 groups and companies exhibited their robotics related projects including autonomous vehicles and climbing robots. While the goal of the block party was to raise awareness of automated systems, artificial intelligence, and robotics, the event was a very good opportunity to present novel automotive systems to high-tech enthusiasts at Stanford and beyond, which lead to a lot of discussion around autonomous driving and what driver assistance can already accomplish today to improve safety and efficiency of the transportation sector.

In June, CARS teamed up with EXPE, the annual Stanford design faire, to feature the prototypes from the Electric Vehicle Design class (see 3.2.2) and to have a special reception at VAIL after the afternoon-long exhibitions on main campus. The vehicles that were presented were an electric kart, an electric bicycle, and a small commuter vehicle as well as a battery test rig that
was used for the solar car project. At the automotive lab, about 50 interested people from academia and industry joined to discuss the student prototypes with the project teams and to celebrate the end of the academic year together, while demo rides were offered in those vehicles as well.

In August, the Stanford Solar Car Project (SSCP) unveiled its latest highly-efficient racing vehicle at VAIL. Before the new vehicle, Xenith, was sent off to participate in the 2011 World Solar Challenge in Australia (see 3.2.8), the undergraduate group invited the community of sponsors, advisers, friends, and enthusiasts to celebrate the completely new-designed vehicle and to give insights into the Solar Car Team’s home that is operated by CARS. About 200 people followed the invitation and listened to the addresses by SSCP, Volkswagen (as the main sponsor of the project), and CARS representatives.

3.4 Regular Affiliates Meetings and Communication

3.4.1 Monthly Affiliates Updates

The Monthly CARS Affiliates Updates present an important component to keep affiliates informed about automotive related topics on campus, to seek their input for events and projects, as well as to maintain a vital community of academic and industry partners. For the year 2011 it was decided to have the one-hour updates organized by default as a telephone conference with the option to meet on campus for those who prefer that. In spring it was further decided to have the phone conferences on an alternating schedule, i.e. early / late in the afternoon, to offer affiliates from Michigan and Japan / Korea to call in at a convenient time. All monthly updates were prepared with itemized agendas and summarized in detailed minutes, which were archived on the CARS website.

The three monthly updates in the first quarter of 2011 were used to prepare and debrief the workshop on "Risk Assessment & Failure Modes for Autonomous Vehicles" and to further extend on the Electric Mobility Workshop that had been hosted at the end of the previous year. Also as part of the meetings, affiliates were updated on the seminar classes that CARS hosted and the resume book, which was distributed to affiliates in February. In addition, CARS announced in March the new membership model to its affiliates, which introduced a new fee structure and different membership levels. The monthly updates were also good opportunities to welcome the new members to the affiliates program, PACCAR, Volvo Cars, and Hyundai, and integrate them into the community.

The monthly updates during the second quarter focused on the Electric Mobility Workshop, which was held in May. Besides the preparation and debriefing of that event, the affiliates were also updated on the spring classes “The Future of the Automobile” and “Electric Vehicle Design”, and also a study on peer-to-peer carsharing was initiated. As much as possible, the monthly updates were scheduled in conjunction with other events, such as the Robot Block Party in April, the Electric Mobility Workshop in May, and EXPE in June to make the affiliates’ visit to campus as effective as possible. The newest CARS member, BMW, was also introduced to the community.

While only 2 monthly updates were held during the third quarter (observing a summer break in July), the meetings were used to discuss the interest and setup for the
Connected Mobility Expert Roundtable, which was eventually held in October. The other major topic was the preparation for the joint trip to the State of Nevada Department of Motor Vehicles in September, after CARS had established a contact between the DMV and its affiliates to discuss the proposed regulation for autonomous vehicles. At the August meeting, Ford was introduced as the newest CARS affiliate and welcomed to the community. At the September meeting, which was at the beginning of the new academic year at Stanford, faculty and researchers from Stanford gave overviews over class projects in design innovation and also research topics in autonomous driving, which were both seeking industry support for their work.

The three meetings in the fourth quarter were mainly used to keep the affiliates abreast with the different student activities in the new academic year, to discuss potential research directions in the connected mobility field following the workshop in October, and to review the entire year at the annual meeting in December. The affiliates could follow the independent studies “Industry Strategies for 2020, “Electric Mobility”, “Risk Assessment for Autonomous Driving”, and “Peer-to-Peer Carsharing” closely through the summaries that were given at the monthly updates. At the meetings, Chrysler and Renault were introduced as the newest CARS members and welcomed to the community.

3.4.2 Newsletter Updates and Website

CARS is eager to keep its affiliates informed with automotive events, activities, and news at Stanford. Therefore, the program had established a news website for its affiliates early on, and sent out news updates at least once a month in 2011. The newsletter typically reached more than 200 recipients at the CARS affiliates and at Stanford. The feedback from the subscribers showed that the newsletter is much appreciated as an essential and efficient way to organize the automotive research community. In addition to the newsletters, more targeted information, such as lecture announcements or organizational matters, was sent out to individuals in between updates if special attention was requested or the timing did not coincide with the newsletter.

All news information was archived at the CARS website, which will be expanded to a more comprehensive source of information for affiliates and prospects in 2012. It is intended to make a database of automotive relevant research publications and a directory of collaborating researchers available on the website.

3.5 Facilities and Infrastructure

3.5.1 Volkswagen Automotive Innovation Lab - VAIL

The Volkswagen Automotive Innovation Lab (VAIL), which is operated by CARS, plays a very important role in being home to most of the automotive research on Stanford campus
and venue for many academic and community events, with almost 90 registered users of the facility. In the second year of its existence, VAIL made classes such as “Electric Vehicle Design” or “Designing Emotion-Reactive Car Interfaces” possible, which require a close interaction with vehicles as part of the learning experience. Those classes had never been offered before, in part because of non-existing facilities, which could have students work on vehicles in a safe and convenient way. The open space also provides for event and project space so that the “Robot Block Part” could for the first time have robots, cars, and 1,000 people together in the same space. The Stanford Solar Car Project continued to benefit from the spacious and functional space at VAIL and the Revs Program at Stanford chose the facility as its hub to prepare its participation in prestigious events such as Monterey Motorsports Reunion and Porsche Rennsport Reunion. As the demand on the operations of the building have grown with the number of projects, events, and people at VAIL, additional support was contracted for general facility management and workshop support tasks.

3.5.2 Experimental Road at Stanford Linear Accelerator Center

In 2010, CARS sought access to a service road at the Stanford Linear Accelerator Center (SLAC) to have an opportunity for testing driver assistance and in-vehicle communication systems in an undisturbed and safe environment. Over the year 2011, no requests were made to use that facility, but it is expected that with the anticipated research in vehicle communication (see 0), the service road will be used for respective testing, especially as 4G cellular communication is readily available in that area. Access to the facility at SLAC needs to be requested in advance and is managed with special permission, in which CARS assists its affiliates with the respective steps.

4 Outlook

CARS will continue to advance research and education in the automotive field and cultivate existing as well as new topics. The main directions will continue to be “Driver Assistance”, “Alternative Energy”, “Connected Mobility”, and “Mobile Society”. In order to advance those topics, the program will focus on initiating new research projects, organize classes, host lectures and events. In all these activities the CARS affiliates are invited to take part and be an active member of the automotive community at Stanford.

4.1 Research and Education

For the year 2012, CARS plans to strengthen the research fields “Electric Mobility” and “Connected Mobility”. It is proposed to turn the directions that were discussed at the different workshops in 2011 into research activities at respective research groups on campus, which could also include post-doctoral assignments. CARS would like to advocate topics with a strong infrastructure or normative aspect, as those in particular
are a good fit with the affiliates program’s mission to pursue topics with a larger group of industry partners.

CARS will also continue to maintain research and study in the “Driver Assistance / Autonomous Driving” realm. As this has been an icon for the affiliates program from the beginning, the affiliates will continued to be supported in connecting with the respective researchers and initiating new research directions. While VAIL is the home for all autonomous vehicles on campus, it is anticipated that the pertaining research will continue to be a core element for activities and events at CARS, and also especially those with strong infrastructure and normative aspects.

For the year 2012, CARS also plans to organize the same classes again, which were offered in 2011. The seminar class “The Future of the Automobile” will be offered in the winter and spring quarters and presents a basis for the project class “Electric Vehicle Design” in spring. The seminar class will offer its affiliates the opportunity to give lectures in class or to propose topics for the interactive discussion sessions, where affiliates are always invited to attend. The electric vehicle project class will solicit proposals for projects that the students want to work on during the previous quarter in the seminar class to ensure that the students use the 10 weeks most effectively to build their prototypes. For the autumn quarter 2012, CARS plans again to have students work on independent study topics, which will ideally be defined together with industry partners. In addition, a class will be co-instructed again at the Business School, which will entertain a theme in the automotive field and seek input from CARS affiliates.

CARS is also proposing “open lab” events, where students and researchers have the opportunity to present their automotive and mobility related work and engage in discussions with the community of academic / industry experts and enthusiasts. This is envisioned as full- or half-day events preferably at VAIL, with project exhibitions, visuals, and brief talks as there is fit. A strong focus will be on the research results from the engineering disciplines, however an interdisciplinary component will be integrated true to the CARS mission.

As the CARS and Revs Programs are growing, it is expected to have closer and even more content oriented exchange in the future. With more and more research being published by the Revs Program and CARS increasing its network on campus and in industry, jointly organized events and activities will be a good way to cultivate automotive topics on campus to everyone’s benefit.

4.2 Events and Activities

CARS will continue to cultivate a community around automotive and mobility related lectures, events, and activities. While many of those will be organized jointly with the Revs program, CARS will keep a strong focus on the future of the automobile and Revs will also tie in a breadth of topics pertaining to the history and culture of the automobile. It is expected that a variety of lectures, community events, and workshops will also be organized in 2012 and affiliates are expected to give input regarding their interest. One example is expected to be a Vehicle Concept Showcase in the first half of 2012, similar to the event in September 2010 at VAIL.

The program considers establishing a regular lecture series beyond the seminar class it is already hosting. While the seminar class offers lectures on a weekly basis and
inspires students for their studies, research, and future careers, the lecture series would host 3-4 special lectures per year and address the broader community of researchers, students, and affiliates with a more formal setting and networking opportunity following the presentations.

4.3 Community

CARS plans to enrich its base of formal affiliates further with IT companies and small business companies as there is fit. While the program will maintain its very much appreciated setting of automotive companies, it has always been able to successfully tie in IT companies for workshops and community events. It is hoped that those external connections can also be turned into a more formal affiliations with the program in the near future.
5 Information for CARS Annual Affiliates Meeting 2011

5.1 Meeting Agenda, final version

**Topic:** CARS Annual Affiliates Meeting 2011
Review of 2011 – Outlook for 2012

**Date / Time:** December 1, 2011 / 10am-lunch, 3-6pm, followed by dinner

**Location:**
- **Morning Workshop 10:00am-1:30pm (including lunch)**
  Volkswagen Automotive Innovation Lab
  473 Oak Rd, Stanford, CA 94305
  Parking permits will be given out on-site

- **Afternoon Meeting 3:00-6:00pm (followed by dinner)**
  Mechanical Engineering Research Lab (MERL), 2nd Floor Conf. Room
  418 Panama Mall, Stanford, CA 94305
  Parking is recommended at metered parking nearby, free after 4pm

**Attendees:**
- CARS Affiliates: BMW, Bosch, Chrysler, Ford, Honda, Hyundai, Nissan, PACCAR, Renault, State Farm, Toyota, Volkswagen, Volvo (typically General Manager / Project Engineer level)

**Contact:** Sven Beiker, beiker@stanford.edu, +1 (650) 714-0536

**Schedule for Morning Workshop**

**10:00** Welcome, Organizational Matters (Beiker)
- Logistics and agenda for the whole day

**10:10** Peer-to-Peer Carsharing – Hype or Trend? (Swenson, Beiker)
- Results from independent study (situation, tech, business), discussion

**10:30** Electric Mobility Across Disciplines (Ganapathy, Rao, Shen, Sprei, Zhong, Beiker)
- Results from independent study (consumers, battery, impact), discussion

**11:15** Strategies for the Automotive Industry 2020 (Dubey, Fogelsong, Gualco, Henchen, Lu, Schoenberger, Setiawan, Tinsley, Wolfe, Beiker)
- Results from Business School class (China, Europe, U.S.), discussion

**12:00** Risk Management for Autonomous Driving (Hsu, Inonu, Smith, Toye, Beiker)
- Results from independent study (situations, failures, remedies), discussion

**12:30** Lunch with Students and Industry Partners (all)
- Follow-up discussion from morning presentations, networking

**1:30** BREAK

*See schedule for afternoon meeting on next page ➤*
Schedule for Afternoon Meeting
Mechanical Engineering Research Lab (MERL), 2nd Floor Conf. Room
418 Panama Mall, Stanford, CA 94305
Parking is recommended at metered parking nearby, free after 4pm
http://campus-map.stanford.edu/index.cfm?ID=02-660

3:00 Welcome, Organizational Matters (Beiker)
- Logistics and agenda for the afternoon

3:10 CARS Review 2011 (Beiker)
- Events, projects, classes (including summary of morning presentations)

3:30 Activities for 2012: Wireless Charging of EVs (Yu, Fuller, Sassoon, Beiker)
- Initial calculations for power transfer, study of overall system, general strategy

4:00 Activities for 2012: Connected Mobility Concepts (McGiffen, Beiker)
- Research program for safety / efficiency relevant vehicle communication

4:15 Activities for 2012: Legal Aspects of Autonomous Driving (Smith, Beiker)
- Summary of first 3 months, outlook for 2012, additional supporters

4:30 Break

4:45 The Revs Program at Stanford (Nass)
- Update on the research program dedicated to the human driving experience

5:05 CARS Website (Tanaka)
- Research database, list of collaborators, general update

5:20 CARS Outlook 2012 (Gerdes)
- Directions for the industry affiliates program

5:40 Open Discussion (all)
- Additional questions, remarks

6:00 End of Meeting

6:30 Dinner at Il Fornaio
520 Cowper Street, Palo Alto, CA 94301
http://www.ilfornaio.com/?page=138&restaurant_id=3151
5.2 Directions to Dinner Venue for December 1, Il Fornaio

- Depart Santa Teresa St toward Roble Dr
  - 412 ft Turn right onto Samuel Morris Way
  - 370 ft Turn left onto Panama St
  - 0.4 mi Turn right onto Campus Dr W
  - 0.8 mi Turn left onto Palm Dr
  - 1.1 mi Turn right onto Cowper St
- 180 ft Arrive at 520 Cowper St Ste 101, Palo Alto, CA

The last intersection is University Ave
If you reach Hamilton Ave, you've gone too far