



# Vehicle Systems Analysis Technical Team Roadmap

June 2013



*This roadmap is a document of the U.S. DRIVE Partnership. U.S. DRIVE (Driving Research and Innovation for Vehicle efficiency and Energy sustainability) is a voluntary, non-binding, and nonlegal partnership among the U.S. Department of Energy; USCAR, representing Chrysler Group LLC, Ford Motor Company, and General Motors; Tesla Motors; five energy companies — BP America, Chevron Corporation, Phillips 66 Company, ExxonMobil Corporation, and Shell Oil Products US; two utilities — Southern California Edison and DTE Energy; and the Electric Power Research Institute (EPRI).*

*The Vehicle Systems Analysis Tech Team is one of 12 U.S. DRIVE technical teams whose mission is to accelerate the development of pre-competitive and innovative technologies to enable a full range of efficient and clean advanced light-duty vehicles, as well as related energy infrastructure.*

*In March 2012, DOE announced a 10-year vision for plug-in electric vehicles (PEVs), called the “EV Everywhere Grand Challenge.” EV Everywhere aims to enable American innovators to rapidly develop and commercialize the next generation of technologies to achieve the cost, range, and charging infrastructure necessary for widespread PEV deployment. As demonstrated in its guiding Blueprint document, EV Everywhere aligns with U.S. DRIVE technical areas focused on electrochemical energy storage, electrical and electronics, materials, vehicle systems and analysis, and grid interaction (for more information, please see [www.vehicles.energy.gov/electric\\_vehicles/10\\_year\\_goal.html](http://www.vehicles.energy.gov/electric_vehicles/10_year_goal.html)).*

*For more information about U.S. DRIVE, please see the U.S. DRIVE Partnership Plan, [www.vehicles.energy.gov/about/partnerships/usdrive.html](http://www.vehicles.energy.gov/about/partnerships/usdrive.html) or [www.uscar.org](http://www.uscar.org).*

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## **Mission**

The mission of the Vehicle Systems Analysis Technical Team (VSATT) is to evaluate the performance and interactions of proposed advanced automotive powertrain components and subsystems, in a vehicle systems context, to inform ongoing research and development activities and maximize the potential for fuel efficiency improvements and emission reduction.

## **Scope**

Unlike other U.S. DRIVE Technical Teams, the objectives of the VSATT are not tied to delivery of the specific technologies that meet U.S. DRIVE goals. Rather, the objective of VSATT is to provide the analytic support and subsystem characterizations that guide technology and system selections and assist U.S. DRIVE Technical Teams in determining performance goals and validation metrics. With that understood, the objectives of the VSATT are as follows:

1. In conjunction with other U.S. DRIVE Tech Teams, conduct analyses and simulations to assess and identify vehicle technology pathways that achieve or best approach U.S. DRIVE Research Goals.
2. Develop system simulation and analysis capabilities needed to support Objective 1.
3. In collaboration with appropriate U.S. DRIVE Tech Teams, perform vehicle, subsystem and component functional evaluations needed to set requirements and targets for alternative propulsion technologies within the scope of U.S. DRIVE and to validate vehicle system simulation capabilities associated with Objective 2. This will include (a) unbiased benchmarking and performance validation of advanced vehicle technologies, and (b) bench testing of components in order to assess their performance and accurately represent their behaviors in a vehicle system simulation environment.
4. Establish and apply testing capabilities needed for Objective 3.
5. Guide and support the maintenance of a vehicle system simulation environment available to all partners that can be used for systems studies of alternative propulsion technologies.

## **Key Issues and Challenges**

VSATT operates as a service organization to other U.S. DRIVE Technical Teams, as well as to the Partnership itself. Consistent with the team's previously described scope, VSATT aims to provide the analytic framework to allow the component technologies developed through the efforts of other U.S. DRIVE Technical Teams to be considered within the context of the complete vehicle system, so that overall benefits of integrated vehicle technologies may be quantified. This is done in support of all four U.S. DRIVE Partnership Goals:

1. Enable reliable hybrid electric, plug-in hybrid and range-extended electric, and battery electric vehicles with performance, safety, and costs comparable to or better than advanced conventional vehicle technologies, supported by the widespread availability of electric charging infrastructure.
2. Enable reliable fuel cell electric vehicles with performance, safety, and costs comparable to or better than advanced conventional vehicle technologies, supported by viable hydrogen storage and the widespread availability of hydrogen fuel.
3. Significantly improve the efficiency of vehicles powered by advanced internal combustion powertrains and vehicle fuel systems while protecting the environment.
4. Improve the efficiency of all vehicle types by using lightweight materials to reduce vehicle mass.

In order to fulfill this analysis/support role, VSATT relies on input from other U.S. DRIVE Technical Teams for component-level performance and efficiency characteristics, and provides output to the other teams to further the understanding of the system-level implications associated with individual component technologies, as illustrated in Figure 1. Due to VSATT's role within the context of the U.S. DRIVE Partnership, a procedural challenge arises in establishing the interaction and communication with the other teams to share the information required to conduct effective analysis. This information sharing is critical for VSATT to achieve its mission, and for the other Technical Teams to align their own targets with Partnership goals.

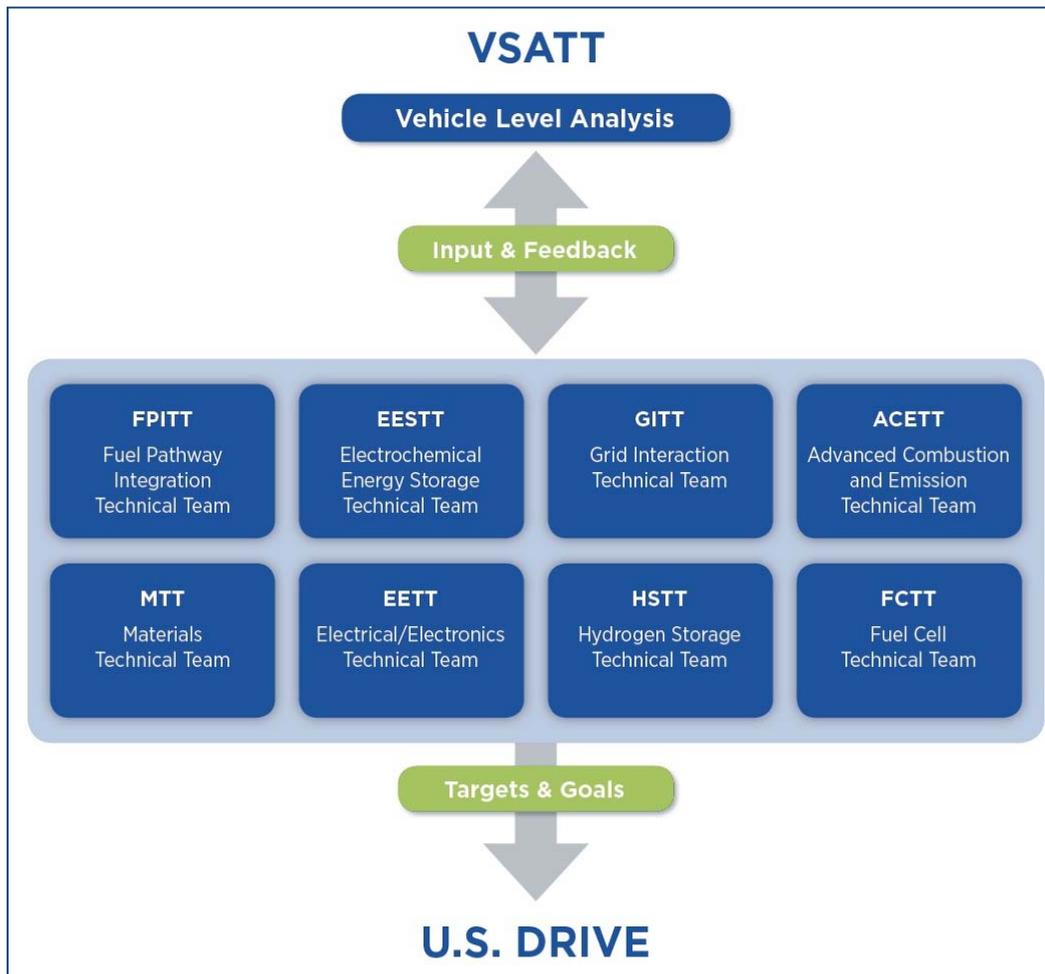


Figure 1. VSATT Interactions with U.S. DRIVE Technical Teams

While VSATT serves to provide the framework in which the Partnership examines components and subsystems in a vehicle-level context, U.S. DRIVE does not set vehicle-level targets. However, modeled vehicle-level performance characteristics must remain consistent across various powertrain and technology configurations within a particular vehicle class, in order to appropriately evaluate the benefits and costs of each particular technology. VSATT faces an additional challenge in defining these representative “reference” vehicle-level parameters with input from the industry partners, while at the same time respecting the need for the automotive manufacturers to protect their proprietary data and competitive positioning.

### Current Status and Technical Targets

The U.S. DRIVE Partnership Research Goals and Technical Targets do not establish technical targets for the vehicle systems analysis activities of the Partnership. Instead the role of VSATT is to provide analytic support and subsystem characterizations that guide technology and system selections and assist U.S. DRIVE Technical Teams in determining performance goals and validation metrics.

In 2011 and 2012, VSATT was involved in supporting the development of a new, analysis-based target-setting process for the other teams focused on vehicle-related research (ACECTT, EETT, EESTT, FCTT,

HSTT, and MTT). This process, which examined a range of possible Partnership targets in a vehicle-level context and relied heavily on the technical expertise of the Tech Teams, including VSATT, aimed to identify Partnership Targets for advanced technologies in the U.S. DRIVE portfolio that would enable vehicles using those technologies to compete with conventional vehicles on a cost and performance basis using a three-year payback period. In addition to providing the analytical capability to evaluate the vehicle-level performance, efficiency, and costs of various powertrain technologies, members of the VSATT provided input regarding the vehicle-level assumptions that ultimately cascade to the requirements and targets for individual component technologies being developed through the efforts of the other technical teams.

## **Gaps and Technical Barriers**

One of the challenges faced by the Vehicle Systems Analysis Technical Team is largely procedural in nature and stems from the VSATT's mission of providing analytical capabilities in support of the other Tech Teams and the Partnership in general. This role requires interaction and coordination with other Tech Teams focused on vehicle-related research. Regular interaction and strong communication between VSATT and other Tech Teams is essential to ensure that VSATT modeling, simulation, analysis, evaluation, testing, and benchmarking activities are leveraged across U.S. DRIVE. To maximize the value of the team's capabilities, the VSATT developed a process (described below) to not only facilitate a more effective information exchange between DOE and the industry partners, but also provide the opportunity for other Tech Teams to work with VSATT to address their vehicle-related analytical needs.

Because of the team's role within the U.S. DRIVE Partnership, VSATT's technical gaps and barriers are not related to a specific component or technology, but arise from the analytical tools and capabilities that allow VSATT to fulfill its mission. For example, modeling and simulation software, as well as laboratory testing facilities and the testing procedures employed therein, form the basis of the technical tool-box which VSATT has at its disposal. Given the dramatic pace of development and improvements in advanced vehicle technologies and components, VSATT faces a technical challenge in continually maintaining up-to-date, validated vehicle component models, and developing appropriate test procedures as new technologies emerge. Maintaining this tool-box in the context of a continuously advancing technology landscape presents an ongoing challenge for which it is not possible to measure progress towards completion. The VSATT will continue to address this challenge as it endeavors to provide analytical support to the Partnership.

## **Strategy**

The two primary elements that comprise the VSATT strategy are (1) the development, maintenance, and use of technical tools and methods (i.e., the "tool-box") that enable the team to fulfill its analytical role; and (2) the processes and procedures by which the team engages and coordinates with other technical teams within the U.S. DRIVE Partnership.

## **Technical Tools and Methods**

A unique set of software tools has been developed and is being utilized by the VSATT to support U.S. DRIVE. The tools are depicted in Figure 2, and are described here. VISION, NEMS, MARKAL, and GREET are DOE tools used to forecast national-level energy and environmental parameters including oil use, infrastructure economics, and greenhouse gas contributions of new technologies, based on vehicle-level simulations that predict fuel economy and emissions. These vehicle-level simulations are done using AUTONOMIE, which allows dynamic analysis of vehicle performance and efficiency to support detailed design, hardware development, and component validation. AUTONOMIE is also used in hardware-in-the-loop (HIL) testing, which allows dynamic control and evaluation of components and subsystems in an emulated vehicle environment. Additional resources available to the VSATT include the Advanced Powertrain Research Facility (APRF) and the Vehicle Systems Integration (VSI) Laboratory, used to test

light- and medium-duty vehicles (operating on a variety of liquid and gaseous fuels), propulsion systems, and components in controlled environments to acquire fuel economy, efficiency and emissions data. Recent advances have also been made in thermal testing capabilities, allowing for complete 5-cycle testing as well as the testing of advanced drivetrain performance at temperature extremes. Additionally, fleet and field tests are used to assess the functionality of technology in the less-predictable real-world environment. These activities are carried out in coordination with one another. For example: data collected from the testing tasks are used to enhance and validate component and vehicle simulation models, as well as to ensure that test procedures and protocols comprehend the needs of coming technologies.

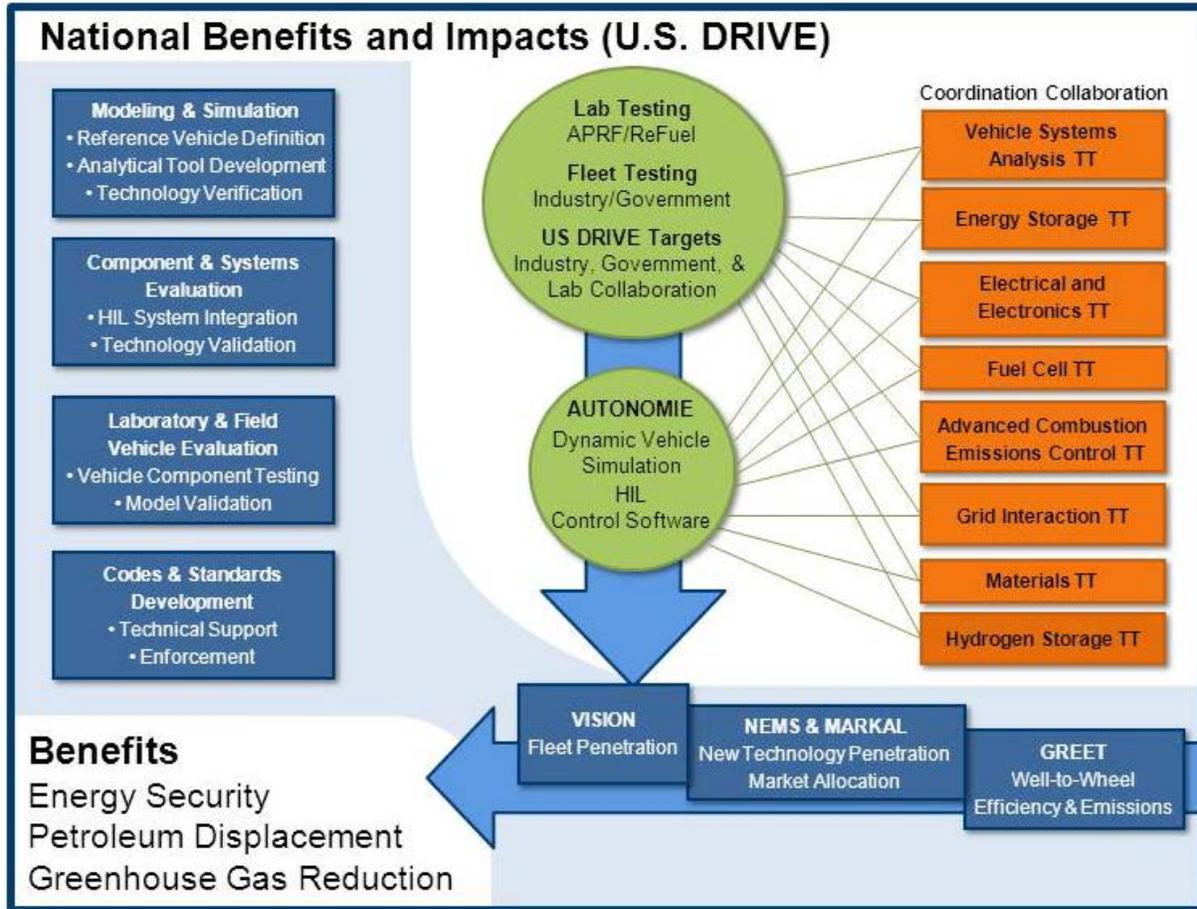


Figure 2. Analytic and Empirical Tools Used to Model and Validate Components and Systems and Benchmark Emerging Technologies

**VSATT Coordination Process**

In order to leverage its technical capability and effectively support U.S. DRIVE, VSATT must encourage, facilitate, and enable the exchange of information and ideas, both internally, among the government and industry members of the team, and externally, with other tech teams, to identify analytical needs within the framework of the Partnership. This communication and exchange occurs in a number of ways. VSATT industry members discuss and identify needs within the automotive industry, seeking input from their counterparts in U.S. DRIVE technical teams; similarly, DOE VSATT members solicit input and ideas from DOE and national laboratory staff. Together, as a team, VSATT DOE and industry members discuss the input received and prioritize needs. Regular joint technical team meetings, focused on specific

intersections and common needs, also provide a mechanism for VSATT interaction with U.S. DRIVE R&D teams, as does the biannual U.S. DRIVE All Technical Team Meeting. The process that VSATT uses to facilitate this exchange of information is summarized in Figure 3 below.

| Time      | Who               | Action   |
|-----------|-------------------|--|
| Feb/Mar   | DOE/OEMs          | <ul style="list-style-type: none"> <li>OEM team members will have a series of iterative meetings to discuss and agree upon a list of topics/needs from the industry perspective. DOE team members will participate in these discussions as needed to provide direction and feedback.</li> <li>DOE VSATT co-chair will meet with DOE co-chairs from other Tech Teams to discuss the needs of other U.S. DRIVE Tech Teams and how VSATT can assist.</li> </ul> |
| Mar/April | DOE/OEMs          | <ul style="list-style-type: none"> <li>During VSATT meeting, both DOE and the OEMs will present the outcomes of their Feb/Mar discussions with other Tech Teams, resulting in a final list of prioritized U.S. DRIVE needs.</li> <li>DOE will supply industry partners with a list of current projects they would like for the OEMs to review during the Annual Merit Review.</li> </ul>   |
| April     | DOE/Labs          | <ul style="list-style-type: none"> <li>DOE meets with Labs to discuss project ideas, identifies gaps between Lab proposals and U.S. DRIVE needs, and evaluates opportunities to maximize alignment between the project portfolio and Partnership needs.</li> </ul>   |
| May       | OEMs              | <ul style="list-style-type: none"> <li>OEM participation on review panel of VSATT projects during DOE’s Annual Merit Review.</li> </ul>  |
| June      | DOE               | <ul style="list-style-type: none"> <li>DOE makes funding decisions for upcoming FY, and provides initial feedback to Labs</li> <li>VSATT team members to communicate as needed to refine project methodologies and share best practices.</li> </ul>  |
| June/July | DOE/OEMs          | <ul style="list-style-type: none"> <li>AMR Follow-up meeting - forum for OEMs to give feedback on VSATT projects that were presented during AMR.</li> </ul>  |
| Aug/Sept  | DOE/OEMs          | <ul style="list-style-type: none"> <li>DOE shares final decisions on planned projects with VSATT OEM members.</li> <li>Team discusses VSATT portfolio .</li> </ul>   |
| Oct/Nov   | DOE/OEMs/<br>Labs | <ul style="list-style-type: none"> <li>Multi-day Project Kickoff Deep Dive – Provide opportunity for team to further discuss project methodologies and execution.</li> </ul>   |

*Figure 3. Annual VSATT Project Process*

In addition, as the only publicly-funded activity that is part of the Partnership, DOE projects provide a convenient pathway to evaluate progress and the utility of publicly-available analytical resources. Aligned with its commitment to active project management, DOE relies on the VSATT as an important mechanism for obtaining critical industry feedback on its projects, including analytical tools and resources. The technical exchange and discussion of assumptions and inputs to analyses, as well as potential opportunities for the expansion and improvement of analytical tools, serve to ensure that DOE-developed resources remain focused on critical needs and complement, rather than duplicate, resources already available to the private sector.

By utilizing its technical capabilities — including modeling and simulation tools, laboratory testing facilities and procedures, and field testing expertise — and using open communication and input from other U.S. DRIVE technical teams, the Vehicle Systems Analysis Technical Team will meet its mission of evaluating the performance and interactions of proposed advanced automotive powertrain components and subsystems in a vehicle systems context. In doing so, VSATT will inform the work of other U.S. DRIVE Technical Teams, and help focus R&D on areas that maximize the potential for fuel efficiency improvements and emission reduction.