Roadmap to the Driverless Vehicle

An SwRI initiative uses Intelligent Traffic Systems technologies to improve the state of the art in autonomous vehicles

By Steven W. Dellenback, Ph.D.

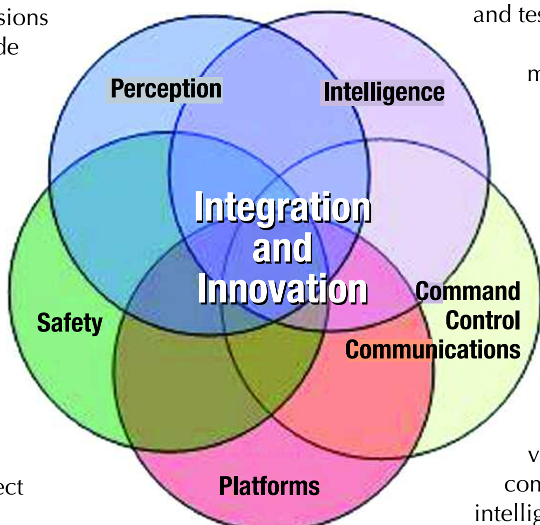
Over the years, technical advancements in automotive vehicle systems have provided steady improvement in efficiency, safety, and comfort for drivers and passengers. However, a new generation of technical advancement is taking the automobile toward a goal many drivers still might consider nothing less than futuristic: the autonomous vehicle.

A new, internally funded research program at Southwest Research Institute (SwRI) is aimed at investigating the development and commercialization of vehicle autonomy as well as vehicle-based telemetry systems to improve safety and facilitate traffic flow. The goal of the Southwest Safe Transport Initiative (SSTI) is to integrate commercially available sensors, software and algorithms into an autonomous vehicle.

The SSTI began in July 2006 with $251,000 in Phase 1 funding. The Institute will invest $3.5 million over the program's two-year lifespan. In the summer of 2007 a major program check point will occur to assure that the program is progessing as scheduled and the technologies being developed are consistent with the evolving marketplace of autonomous ground vehicles (AGVs).

Initially, five of SwRI's 11 technical divisions are participating in the initiative. They include the Engine, Emissions and Vehicle Research; Aerospace Electronics and Information Technology; Automation and Data Systems; Applied Physics; and Mechanical and Materials Engineering Divisions. The initiative is guided by an oversight committee whose members include the vice presidents of the participating divisions.

SSTI strives to exploit the significant work in recent years of the DARPA (Defense Advanced Research Projects Agency) Challenge program involving AGVs, and also to add SwRI's own innovations to advance AGV technology. SSTI project results are expected to be of interest to the autonomous vehicle research community, especially to agencies such as DARPA, the Department of Defense and the Federal Highway Administration. Each has expressed interest in aspects of autonomous vehicle technology. For instance, the Department of Defense and Congress have estimated that one-third of ground combat vehicles will be unmanned by 2015. Meanwhile, high-value commercial vehicles such as 18-wheelers, construction equipment, and specialty vehicles for supply logistics and deliveries are expected to readily incorporate automated safety features.

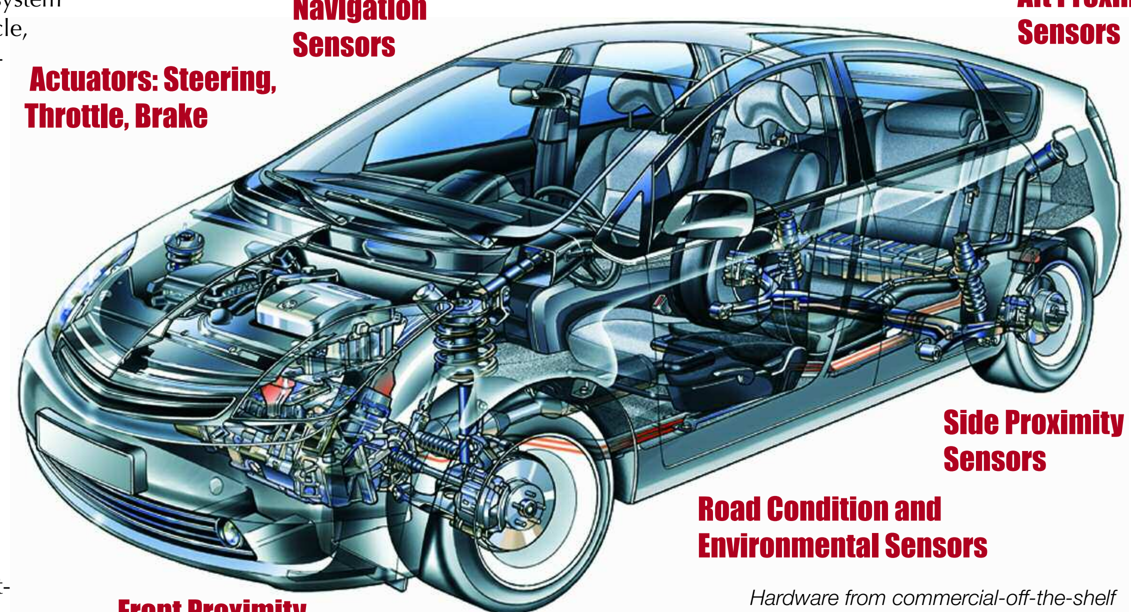


A series of separate research areas are integrated into the SSTI mission to develop technologies for autonomous vehicle capabilities.

The initial goal of SSTI is to develop an SwRI-designed system to demonstrate vehicle autonomy and sensor monitoring. Its functions will include modeling, simulation, hardware-in-the-loop, software-in-the-loop, inter-vehicle communications, mission rehearsal, mission forensics, and demonstration and evaluation capabilities. The program is focusing on acquiring advanced sensor, perception and intelligent automation technologies through purchase or collaboration, and then advancing these technologies as they apply to autonomous vehicles to enhance mobility and safety. A by-product will be an autonomous vehicle that can be used as a demonstrator and test platform for ITS technologies.

The state of the art in autonomous vehicle mobility can be summarized into five categories: robust driver-assist functions such as adaptive cruise control, stability control, lane keeping and parallel parking; relatively robust autonomous operation in highly controlled environments using waypoint navigation, road following and avoidance of static obstacles; segregated functionality for autonomous operation in unconstrained, on-road, urban environments using lane-keeping, vehicle-following, lane-changing and related capabilities; cooperative vehicle-highway systems using vehicle-to-vehicle and vehicle-to-infrastructure communications to link intelligent vehicles with intelligent highways and with each other; and strategic coordination of grouped AGVs for tasks ranging from battlefield AGV teaming to optimized traffic flow and autonomous border sentry activities.

In the on-road domain especially, many parts of the autonomous driving problem already have been solved individually, including many key highway driving problems. What hasn't yet been achieved is a highly robust system for autonomous, multi-vehicle, on-road operations in a genuine urban environment.



Hardware from commercial-off-the-shelf sources, combined with SwRI-developed integration software, provides the sensor, communication and navigation capabilities needed for autonomous operations.

Technical Approach

The research program consists of improvements in hardware, software, simulation and modeling, system safety and reliability. All of these culminate in the development and demonstration of a functional AGV. The basic approach is to acquire, either through collaboration or purchase, existing hardware and software components representing advanced technology that can be adapted to the program's objectives. The components not only are being integrated into a functional AGV but also are providing a platform for research to demonstrate other emerging technologies.

Hardware

The base vehicle for the AGV project, a commercially available sport utility vehicle, is being modified both mechanically and electrically to allow installation of perception sensors, computer platforms and support software, a system for communications, command and control, a data logger and a system health monitor. Substantial effort was made to identify existing hardware systems that are scalable enough to allow for augmentation, modular enough to allow individual components to be removed while maintaining functionality, flexible enough to allow parallel development of different components, and reliable enough for rugged service through the use of robust and redundant systems. Selection of hardware components is based on a balance of the capabilities, size, ease of use and cost.

The perception system consists of sensors and software to identify the environment, obstacles and terrain, as well as the vehicle's internal state. A system that combines sophisticated global positioning system (GPS) and inertial navigation allows for determining the vehicle's location and planning its route. The onboard intelligence is implemented using hardware and software that melds situation awareness and knowledge representation while planning and executing the AGV's route. Another intelligence interface is communications hardware. Dedicated Short Range Communication (DSRC) radios are being considered for vehicle-to-roadside and vehicle-to-vehicle communications.

The command-and-control hardware is the system that takes path information supplied by on-board intelligence and makes the commands necessary to move the vehicle so as to minimize the error between the planned and actual paths. This hardware is based on a computer platform running under a true real-time operating system. The system will send commands and receive feedback from a drive-by-wire system that controls the vehicle's transmission, brake, accelerator and steering.

Software

The SSTI's software architecture design is based on algorithms and frameworks that are available from organizations with a long history of AGV development. Program designers decided early on that the greatest chance for success in a fast-track development effort was to build on available software bases. The software framework allows software modules to be used cooperatively and enables data fusion by "plugging in" the inputs and outputs of independent software modules. It also allows new AGV platform components to be developed quickly and added easily.

A simple graphical user interface allows the AGV operator to identify the trip's objectives, determine what portions of the trip are to be under autonomous control, plan a path and then monitor the system's operational constraints. The interface uses a touchscreen pad and a keyboard installed in the AGV. ❖

Questions about this article? Contact Dellenback at (210) 522-3914 or steven.dellenback@swri.org.

Acknowledgments

The author wishes to acknowledge the technical contributions from a number of SwRI technical staff members including Roger Lopez of the Aerospace Electronics and Information Technology Division, Ryan Lamm of the Automation and Data Systems Division, Dan Pomerening of the Mechanical and Materials Engineering Division and Joe Steiber of the Engine, Emissions and Vehicle Research Division.