WWW.GPSWORLD.COM

GPS World

THE BUSINESS & TECHNOLOGY OF GNSS

AUGUST 2013

UAV/UGV

TARGET ROBOT TAKES A HIT FOR SAFETY

PLUS

DETECTING UNDERGROUND NUCLEAR EXPLOSIONS

PRODUCT SHOWCASE

GNSS ALMANAC

Photo Brian Geiger.

Robot: Target on Its Back

Two Autonomous Vehicles Seek Safe Avoidance in Critical Tests

A new state-of-the-art research center runs car-makers' safety systems through their paces, in tandem with a soft-target robot that can be crash-impacted without adverse effects. Precise positioning and exact repeatability of test sequences are key criteria.

Paul Perrone, *Perrone Robotics*

The Insurance Institute for Highway Safety has undertaken a $30 million expansion project at its Vehicle Research Center near Washington, D.C., enlarging and enhancing a state-of-the-art vehicle test track and building a new 700 x 300-foot (213 x 91-meter) covered track for weather-resistant testing.

The VRC will use new robotic and positioning technologies to achieve required levels of precision and repeatability for vehicle testing of frontal collision avoidance and other safety systems. Tests of both the same and different vehicles must be conducted under identical, controlled conditions for the results to have comparable fidelity.

Crash tests and research conducted at the VRC help drive life-saving improvements in vehicle designs. The new facility will enable staff to evaluate emerging automated vehicle technology in commercial vehicle systems intended to prevent crashes or lessen their severity, with the goal of encouraging the entire industry to adopt the most effective new features.

Safety systems in vehicles to be tested include the following:

- Adaptive cruise control
- Collision-imminent braking
- Lane-departure warning/correction
- Other automated technologies.

Such functions represent semi-automated functions aboard vehicles now on the road. The system is also designed to address and test the full spectrum of semi- to fully-automated vehicles, addressing evolving levels of autonomy and ultimately producing driverless vehicle technology.

IIHS has contracted Perrone Robotics, Inc. (PRI), to deliver a robotic system for testing such vehicles. PRI develops new applications using its MAX robotics and suite of automation software building blocks. MAX enables rapid integration of a range of sensor and actuator types and has evolved with several frameworks, including MAX-UGV for unmanned ground vehicles. PRI has used MAX-UGV to build automated passenger cars, all-terrain vehicles, tractors, custom platforms, and rockstar Neil Young's long-range electric LincVolt, a converted 1959 Lincoln Continental.

For the first phase of the IIHS project, the Perrone Robotics system includes a robot target vehicle with the footprint of a car, but measuring only 4 inches high, with a 1-inch ground clearance (see **OPENING PHOTO**).

Test Scenario Example. One instance to be tested is National Highway Traffic Safety Administration criteria for crash-imminent braking (CIB). The CIB concept goes beyond the forward-collision warning systems already found in many new cars by actually engaging the brakes when a driver, at fairly slow speeds, gets too close to the car in front of him. In tests, the while the test vehicle travels at similar speeds on a programmed collision course with the robot.

The target robot vehicle carries one of a number of soft targets. If the vehicle under test fails to prevent a collision with the robot target, the test vehicle runs over the robot target vehicle, dislodging the soft target, but avoiding damage to the test vehicle, robot target vehicle, and the soft target. The next phase of the project adds smaller-footprint target robot platforms with soft targets, representative of pedestrians and cyclists.

To ensure that the test vehicle can perform repeatable tests, the system also includes a drop-in actuator kit that can be installed into any test vehicle in 30 minutes or less. The system is designed to allow a human driver to sit comfortably in the vehicle and optionally drive, but can also control the throttle, brake, and steering to drive test profiles. Repeatability is key for the operation of robots and vehicles, as well as track conditions, which will be helped by the covered track.

The VRC test track is installing Locata as its positioning system. In addition to alleviating concerns about GPS outages or dead/weak signal spots, this enables the PRI system to be operated reliably inside the new covered test track. While GPS is not an option for covered or indoor test sites and suffers from environmental issues, the high fidelity and localized positioning provided by Locata overcomes these barriers to test.

PRI will deliver the target robot and drop-in actuators custom-built. The company looked at starting with existing platforms and building from them, but it would have been infeasible or overly expensive to meet the IIHS requirements for this system. Most existing systems were developed for vehicle dynamics testing or low-speed/simple collision testing. Most couldn't handle some or all of the more challenging requirements such as the following:

Drop-in actuator kit:

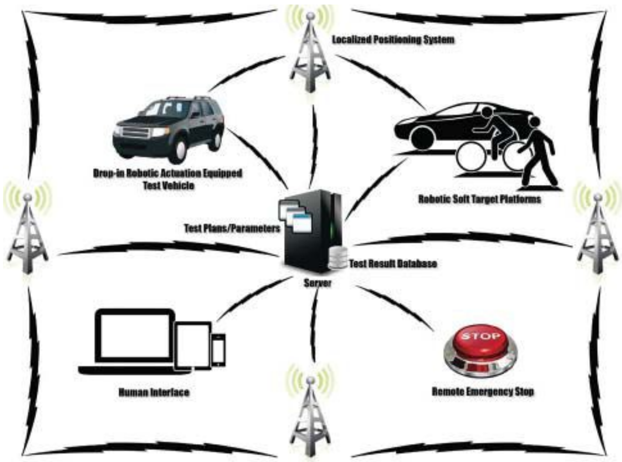
- Allow human driver to sit comfortably and drive the vehicle without interfering;
- Drive autonomously while also allowing for hybrid modes whereby test drivers and onboard systems may assist or take over controls;
- Offer out-of-the-box programmability and flexibility to handle a wide range of test scenarios and automated vehicle levels;
- Install into any vehicle in 30 minutes or less;
- Do not damage vehicle with installation; retain a significant percent of resale value.

Target robot vehicle:

- Accelerate from 0 to 55 mph in 10 seconds;
- Survive collisions at speeds up to 55 mph;
- Allow collision-avoidance testing with minimal damage to test vehicles and target robot;
- Scale for carrying a wide variety of soft-target payloads and enable a wide range of vehicles, from small car to SUV to tractor-trailer) to be tested.

Locata positioning system:

- Work outside and also on covered track; cover track area with no dead/weak spots;
- Deliver better than 10-centimeter accuracy for position measurements and relative position control of robots and vehicles;
- Deliver position updates at 100 Hz in combination with attitude and heading reference system (AHRS) or inertial navigation system (INS).



▲ **FIGURE 1** PRI test system.

▲ **DROP-IN ACTUATOR KIT** steering (top) and throttle-brake (bottom).

▲ **A HUMAN OPERATOR** is easily accomodated within the drop-in actuator kit.

The positioning requirement derives from the testers' need not only for accurate location data of each vehicle, but for precise knowledge of how far apart they are while performing real-time control to orchestrate repeatable scenarios, intersecting vehicle and robot paths to determine whether the vehicle acts to prevent a collision.

Safety Systems

There is a driver in the test vehicle, and there are personnel present at the test site who could be injured by a test vehicle or target robot platform. In addition to wireless e-stop remotes, the test vehicle and target robot systems can be disabled and stopped by a number of events. In the target robot, an e-stop causes the battery pack to be completely disconnected from all vehicle systems, and a spring-load is released applying mechanical braking to stop the vehicle. Under normal conditions, the spring is held back with a pneumatic system and air is dumped upon e-stop event. A target robot e-stop is triggered by

- remote e-stop controller
- a command issued by control software
- loss of communication with external systems
- failure of or loss of communication with internal systems
- loss of power.

Aside from fail-safe remote and onboard e-stop systems, additional safety measures are employed by means of safety controllers that monitor safety-critical regions of software, implement a wide range of robot-safety checking rules, and ensure that the robot is operating within safe parameters of the environment (such as by staying within an invisible fence and pre-defined operation boundary).

Common MAX-UGV Robot Logic

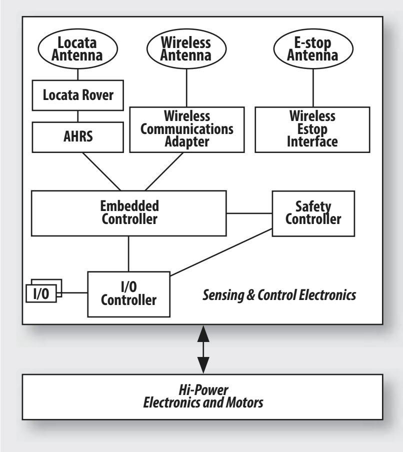
A common instrumentation and control system (CICS) for both the target robot platforms and test vehicle instrumentation and robotic assist platforms is illustrated in FIGURE 2.

Embedded Controller. The heart and soul of the vehicle hosts and runs the algorithms, receives sensor data, and executes actuation commands to the motor controllers based on desired route plans and dynamic sensor information. This controller runs the MAX software platform, MAX-UGV framework, and various MAX drivers.

I/O Controller. Handles inputs from sensors for temperatures, voltages, and currents as well as monitoring limit switches and actuating relays. Certain controls are planned such as mock brake lights on target robots and warning lights in test vehicles.

Locata. A constellation of nine LocataLite units on towers covers the existing track for Phase I of the project. Phase 2 will require additional units to add coverage to the covered track; some towers will provide coverage to both tracks. Each target robot vehicle and each drop-in kit for the test vehicles carries a Locata rover.

Locata's new software essentially adds some capability from its indoor software to its outdoor software to deal with reflections/multipath issues caused by the metal buildings at the test site. The new software also allows the rover to perform real-time calculations on board, required for the less-than 10-cm accuracy. Previously this had to be done on a separate system and data had to be transferred back and forth, which worked against meeting real-time position update requirements for controlling speed, position, and relative position of robots and test vehicles. In test vehicles and target robots, the Locata rover position updates are merged with the output of an attitude, heading, and reference system (AHRS).



▲ **FIGURE 2** Target robot logic flow.

AHRS. The CICS in the robots and test vehicles includes an AHRS that provides the required heading, position, and velocity updates. Accuracy requirements are heading, 1 degree; position, less than 10 centimeters; velocity, 1 mph. Our required position update rate is 10 Hz. We expect to achieve 100 Hz in our system, which improves self-nav capability and overall performance. This rate also applies to other measured/logged data. A Kalman filter computes data from sources within the AHRS and from external sources: GPS and Locata.

Wireless Adapter, Antenna. On our critical channel, we exchange messages between vehicles to effect proper trajectory and relative positioning. Our e-stop controllers and safety systems also use this network. The non-critical channel is used for test setup and supervisory control, decimated data transmission for HMI monitoring, and logged data transmission.

Wireless E-stop Interface. This interface is for remote shutdown of a vehicle. The e-stop triggers are similar for the test vehicle systems, but the driver can also disable the robotic system. Rather than brake the test vehicle, an e-stop of the test vehicle systems disables the steering, brake, and throttle actuators into limp-mode and releases control of the test vehicle to the driver.

Safety Controller. A separate watchdog

*See **ROBOT**, page 44.*

■ **MACHINE CONTROL** / PRECISION AGRICULTURE

Network RTK Repeater

The Settop Repeater allows network RTK rover use in areas of low- or non-GSM coverage by receiving differential corrections via radio. A new firmware update allows connection via any external radio to connect the repeater to precision agriculture systems or machine control. Repeater field application versatility is managed by intuitive software using a touchscreen.

Settop Survey, *www.settopsurvey.com*

■ **WIRELESS** / TIMING

Durable Antenna

The VIC100 Series antenna is an active L1 GPS antenna designed for timing and synchronization. It offers immunity to noise and interference, and secure performance by attenuating noise and interference near the GPS L1 frequency through triple-filtering design. The VIC100 Series is housed in a waterproof enclosure designed for excellent performance under severe environmental conditions. Its shape prevents accumulation of snow and ice, eliminating problems with bird perching and enhanced immunity to lightning surge.

Panasonic, *panasonic.com/gps*

■ **OEM** / SIMULATOR

Multi-Frequency Record and Playback System

The SS6425 multi-frequency GNSS record and playback (RPS) test system provides RF recordings for GPS, GLONASS, Galileo, BeiDou, and QZSS constellations; L1, L2, L5 frequencies; 30-MHz bandwidth; and more features than the company's previous systems, to support a wide range of positioning and timing test applications.

The test system is self-contained and portable, enabling users to record and play back data in the field without the need for an additional PC or external power. Complex signal conditions can be faithfully captured and replayed, including urban environments, indoor spaces like airport terminals, and dense forests. Multiple environments can be brought into the lab and replayed in a repeatable and controlled manner, helping developers improve receiver and system performance.

Spirent Communications, *www.spirent.com*

■ **SURVEY** / MAPPING

Integrated GIS Receiver

The HiPer SR for GIS is a compact, integrated GNSS receiver with sub-meter accuracy. Scalable options are available via OAF (Options Authorization File) upgrades, delivering accuracy levels of sub-decimeter and centimeter without the need for additional hardware.

The HiPer SR for GIS can be paired with a Topcon controller and eGIS software, or used with Topcon's eGPS utility software to use a third-party device and application such as ArcPad or ArcGIS mobile running on a Windows tablet or mobile device.

HiPer SR features the 226-channel, universal tracking capable Vanguard chip for unmatched performance flexibility, and can be used for jobs such as locating utilities within an inch or providing sub-meter accuracy for an environmental study.

Topcon Positioning Systems, *www.topconpositioning.com*

Robot

Continued from page 32

controller monitors live conditions and the embedded controller and onboard systems, and serves as a direct line for remote wireless e-stop.

Electronics, Motors. These includes six high-performance 4-inch motors, motor controllers, cut-off contactors, and overall cut-off system for e-stop.

Conclusion

The IIHS expansion project is a first of its kind for automated vehicle testing, breaking new ground for target positioning and control, and providing the first indoor test track for this purpose. Data from these tests will be used to improve safety of on road semi- and fully-automated vehicles and help save many thousands of lives, setting a high bar for capability and performance of all automated vehicle functions. Requirements for safety, repeatability, and seamless handoff between driver and autonomous control of the test vehicles, as well as the speeds at which the robots must travel and survive collisions, pose significant challenges. We believe our systems meet them fully.