



Crash Science Meets the Courtroom: Robotics and Reconstruction in Action

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A pickup truck is driving in a residential area and swerves to avoid a collision with a bicycle, striking an oncoming vehicle. Data has been downloaded from the vehicles involved, and accident reconstruction experts have performed an on-site inspection, but the client wants to know: *Could the driver of the pickup see the oncoming vehicle when deciding to swerve? Would an Advanced Driver Assistance System (ADAS) have prevented the accident?* By combining innovative testing tools, such as driving robots, with a skilled and dedicated engineering team, S-E-A performs repeatable, safe, and data-driven analyses to help answer questions to uncover additional insights relevant to a case.

Driving robots enable the precise, repeatable testing required for recreating incidents for litigative matters. By controlling the speed and path of a vehicle, accidents can be recreated without requiring a human driver, making it safe to test scenarios and demonstrate what happened. With the repeatability of a robotic controller, S-E-A can dictate the variables of interest, such as path or speed, while determining what happened based on enabling or disabling other systems. Similarly, a steering robot provides the ability to record and follow paths of any shape or size, to replicate a specific steering wheel angular velocity (simulating a quick turn versus a slow turn), and to perform standardized tests. This type of capability has enabled us to drive vehicles into other vehicles, all-

rain vehicles into sticks embedded into the ground, and to test vehicles to their limits with hours of continuous automated steering – all with path following within an inch. By applying gas and brake inputs, vehicle speed control can be performed to follow a specific speed profile or apply a brake input at some time after an alert. To support accident reconstruction work, we've performed tests at iterative speeds using the brake and throttle robot and by matching damage, have been able to help determine the likely speed prior to impact.

with passenger vehicles, soft target cars, and semi-tractor trailers, at a variety of speeds and for many different clients.

To recreate the accident described involving the pickup truck and bicycle, S-E-A installed driving robots in both vehicles used in the crash scenario. Each was programmed to perform a specific driving path (shown in *Figure 1*) and at a specific speed that investigators determined matched the exact accident scenario. S-E-A then also used the STRIDE robotic platform to carry a bicyclist target into the path of the

vehicle. This provided a visual stimulus to show what the driver of the pickup truck could see and when the driver could first see it. This test was performed with exemplar vehicles, and the crash evidence, skid marks, Event Data Recorder (EDR) data, and other information were compared to those collected from the accident scene and vehicles involved. The test was then repeated with a soft target car to allow for many variations in conditions without causing damage to the pickup truck exemplar. See *Figure 1*.

With all of the critical data, our imaging sciences team was then able to create an accurate animation of the incident. Points of View (POV) were created for the driver of the opposing vehicle, overhead views, and similar, as shown in *Figures 2 and 3* on the following page.

Similar tests have been performed with an onboard ADAS system to avoid or miti-

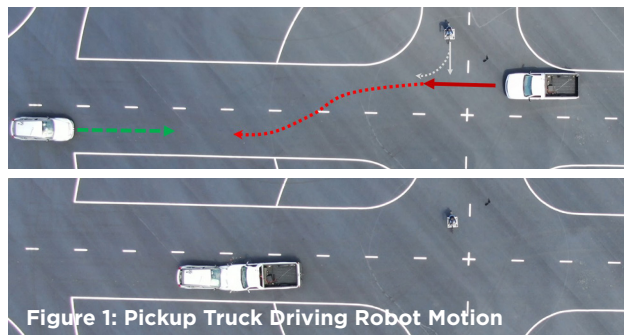


Figure 1: Pickup Truck Driving Robot Motion

Most accidents are not traditional straight line or perpendicular line (T-bone) vehicle travel paths – with our driving robots, we can safely and easily reproduce any accident scenario, whether traditional or unique. Let's say that you want to recreate an accident where one or more vehicles are traveling along a changing path (a right/left turn, a sideswipe during parking, or a quick lane change prior to a collision). S-E-A has recreated each of those scenarios

gate the collision, with vehicle conditions changing (different vehicles, alert settings, speeds, etc.), or with additional inputs or stimuli. In the pickup truck and bicyclist example, the analysis focused on whether an ADAS system would have braked to avoid the bicyclist, eliminated the need for driver steering, or issued an earlier warning. A study was done using the same inputs and several different vehicles to evaluate whether a sample size of comparable vehicles equipped with an Automatic Emergency Braking system for bicyclists would have responded.

Our driving robots have also been used to support case testing by instigating a tractor-trailer rollover. In this case, S-E-A was tasked with performing a steering maneuver at speed to get the trailer to rollover, as trailer rollovers typically precede tractor rollovers. To do this testing safely without risking the driver, we installed our driving robot systems in the tractor. After instrumenting both the tractor and the trailer with systems to record speed, position, accelerations, angles, and roll rates, the driving robots were used to perform a fishhook-type steering maneuver to instigate the unmanned rollover event. In this case, a wireless network and redundant safety systems allowed the testing to be monitored from a safe distance away, and speed gates and other checks in the software ensured that if conditions were not optimal to complete the test (e.g., speed was lower than tolerance), the maneuver would not be instigated. For tests limited to a single execution due to potential vehicle damage, this method is commonly employed to help ensure a successful result.

We have also used our driving robots to perform litigative support testing on off-road vehicle products – placing driving robots in vehicles and inducing rollovers or trip-overs to replicate damage and confirm the conditions preceding an incident. Off-road testing with driving robots involves tightly controlling steering input and speed control to follow a path and maintain speed over bumpy and uneven terrain. Vehicles with traditional controls (like a recreational off-road vehicle) can use the standard S-E-A driving robots, but vehicles like an all-terrain vehicle (ATV) or a zero-turn lawnmower require specialized actuators. An example of a tripped rollover of an ATV with a test dummy mounted is demonstrated in *Figure 4*.

Recreating vehicle accidents often involves the use of an anthropomorphic test device (ATD), also known as a test dummy. An ATD can be used to study occupant motion during a crash event, represent the human weight component of a vehicle

Figure 2: POV of the opposing vehicle



Figure 3: Overhead view of scenario

system, and assess potential injury exposure via instrumentation in the head, neck, chest, and other areas. When test scenarios are safe enough to involve live volunteers in accident recreation, motion capture and other sensors can be used to study the accelerations and motions experienced by the occupant. Between creating accurate animations of human movement while climbing into a semi-tractor, capturing a human



Figure 4: Rollover of Unmanned ATV with Test Dummy

subject's response to automatic emergency vehicle braking, and providing input to biomechanical simulation software, S-E-A's motion capture capabilities are useful across a range of imaging and biomechanical applications, and these marry well with the use of driving robots.

Driving robots can also be used in conjunction with other equipment. For example, S-E-A regularly uses driving robots to control vehicle inputs while using the STRIDE robotic platform to bring a pedestrian target into the vehicle path. This is part of vehicle ADAS testing on automatic emergency braking, rear cross-traffic, or pedestrian systems. Gradual lane deviation can be generated with the steering robot to simulate a driver drifting out of a lane to test lane departure warning or lane keeping systems, while the distance between the vehicle and the lane lines is accurately measured. Time-synchronized data can be recorded with low-latency tools such as cameras and microphones to provide a timeline of vehicle alerts and warnings over the duration of a test.

Real-world vehicle testing and corresponding visuals leave an impact on juries and the opposing side that cannot be understated. With drone and in-vehicle video, crash tests provide insight into occupant dynamics and vehicle damage in a way that takes traditional simulation and reconstruction to a new level. Instrumentation in vehicles and ATDs captures accelerations, forces, and speeds to provide a clear idea of the components of a vehicular event. The multidisciplinary approach means that experts from human factors, vehicle accident reconstruction, biomechanics, and imaging sciences combine to analyze reaction time and occupant injury data, create demonstratives for trials, and create thorough and complete reports and visuals. From pedestrian impacts to tractor rollovers, and from zero-turn mower accidents to multi-vehicle collisions, a range of repeatable, accurate, and safe testing methods can be employed to bring greater insight and clarity to any case.



Meredith Bartholomew is a senior research engineer at S-E-A. In this role, she performs vehicle testing for clients such as original equipment manufacturers, government agencies, and forensic clients. Her background and experience include more than 10 peer-reviewed published works with a focus on vehicle testing in the ADAS space. Meredith has both a bachelor's and a master's degree in mechanical engineering from The Ohio State University.