

## Development of a Guided Soft Target for Crash Avoidance Technology Evaluation

2011-01-0580

Published  
04/12/2011

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doi:10.4271/2011-01-0580

### ABSTRACT

As Advanced Crash Avoidance Technologies (ACATs) such as Forward Collision Warning (FCW), Crash Imminent Braking Systems and other advanced technologies continue to be developed, the need for full-scale test methodologies which can minimize hazards to test personnel and damage to equipment has rapidly increased. The challenge of evaluating such ACAT systems is twofold. First, the evaluation system must be able to deliver a potential Collision Partner (CP) reliably and precisely along a trajectory which would ultimately result in a crash in a variety of configurations, such as rear-ends, head-ons, crossing paths, and sideswipes. Second, and more importantly, the collision partner must not pose a substantial physical risk to the test driver, other test personnel, equipment, or to test vehicles in the event that the collision is not avoided.

A Guided Soft Target (GST) system has been developed to provide a versatile test methodology for the evaluation of such crash avoidance technologies. This system can be used to replicate a wide range of crash scenarios while minimizing physical risk. The GST system comprises a soft target vehicle or pedestrian form, a programmable, autonomously guided, self-propelled Dynamic Motion Element (DME) and a wireless computer network. The system accommodates virtually any type of collision between the GST and the subject vehicle, and performs closed-loop control to ensure that the GST arrives at the intended collision point at the same instant in time as the subject vehicle. In another mode, the GST arrives at the target location at a specified time and with a specified speed.

### INTRODUCTION

The continuing development of Advanced Crash Avoidance Technologies (ACATs) has precipitated the need for effective methodologies to evaluate such systems. However, the challenges facing the evaluation engineer in this regard are substantial. First, in order to evaluate a crash avoidance or mitigation system effectively, the Collision Partner (CP) must be propelled and guided reliably and precisely along a trajectory which would ultimately result in a crash. Second, especially in the case of crash mitigation systems where the system must be evaluated well into the crash imminent phase of the conflict, the CP must not pose a substantial physical risk to the test driver, other test personnel, equipment or test vehicles in the event that the collision is not avoided. This second challenge is the most important and difficult to address.

Recently, an innovative evaluation methodology has been developed to address these requirements, using a Guided Soft Target (GST) system. This system can be used to replicate the pre-crash motions of the CP in a wide variety of crash scenarios while minimizing physical risk. The GST system comprises a soft target vehicle or pedestrian form, a programmable, autonomously guided, self-propelled Dynamic Motion Element (DME) and a wireless computer network. The Soft Car or Soft Pedestrian is intended to be a realistic representation of a CP for both the driver and the system under evaluation, and the DME serves as a means of conveyance for the Soft Car such that the motions of the CP are realistic. As a fully autonomous vehicle, the GST can coordinate its motions with the subject vehicle during the pre-crash phase such that the initial conditions of the crash phase are replicated from run to run. At the instant that the ACAT or subject vehicle driver begins to respond to the conflict, the GST can automatically switch to a mode in which its speed and course are no longer coordinated with the position of the

subject vehicle, but instead are such that the GST follows a predetermined speed/time/distance trajectory to a target ground-fixed impact point. This enables the analyst to determine the effect of the ACAT system on the subject vehicle's potential impact with, or avoidance of, the GST as it arrives at the target impact point (e.g., the change in such indices as the "resultant relative velocity at minimum distance" (RRVMD), minimum distance (MD), etc.).

Other systems and methods have been developed to assist in the evaluation of ACATs, while assuring test personnel safety in the event of collisions. Such systems and methods include the use of stationary balloon cars [1], towed target vehicles [2, 3,4], autonomous crash partners [5], and dedicated test facilities where the subject vehicle is held stationary while the collision partner moves relative to it [6]. Comparing and contrasting the GST to these other methods is beyond the scope of this paper. However, the authors are unaware of any other methods or test systems in which both the subject vehicle and collision partner move realistically at relatively high speeds up to and through the point of impact, while minimizing physical risk to test personnel and equipment.

## SYSTEM ARCHITECTURE AND FUNCTION

The GST system comprises three computers which communicate via a Wireless Local Area Network (WLAN) and perform specific functions. Figure 1 illustrates the overall architectural layout of the GST system, which includes the following nodes and their associated peripheral equipment:

- Subject vehicle
- Base station
- DME

The subject vehicle computer performs the various data I/O functions within the subject vehicle, and provides the measured data to the rest of the system. Additionally, the subject computer controls discrete events within the subject vehicle. The subject vehicle node comprises the following components:

- Notebook computer
- Differential GPS receiver
- Tri-axial accelerometer
- Digital I/O board to monitor and control discrete events (e.g., sense ACAT warning on/off, illuminate LEDs, initiate open-loop braking, provide audible alerts)
- Wireless LAN bridge

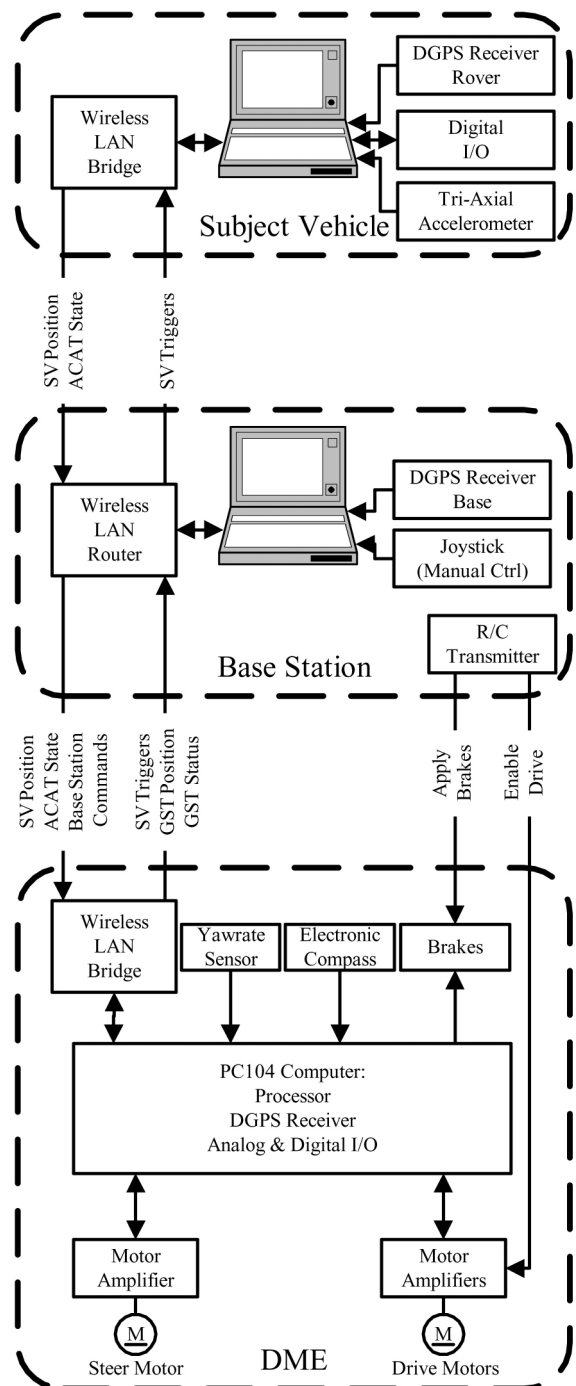


Figure 1. GST System Architecture

The Base Station acts as the central hub for all communications and allows the operator to monitor and control the system. The base station comprises the following components:

- Differential GPS (DGPS) base station receiver
- Notebook computer
- Joystick

- Wireless LAN router
- Radio transmitter to provide emergency-stop capability

The Base Station computer allows the system operator to run a complete suite of tests from a single location. From the base station computer, the operator performs the following functions:

- Setup and configuration of subject vehicle and GST computers via remote connection
- Monitor subject vehicle and GST positions, speeds, system health information and other system information
- Setup of test configuration
- Test coordination
- Selection of GST modes
  - Hold
  - Manual
  - Semi-autonomous
  - Fully Autonomous
- Post-test data analysis

The DGPS base station receiver provides corrections to the roving DGPS receivers in both the DME and the subject vehicle via the WLAN. This is accomplished without the need for a separate DGPS radio modem, minimizing the number of antennas on each node of the system. This is most important in the case of the DME, since all connections to antennas must be made frangible, such that they can separate from the DME in the event of a collision with the Soft Car.

The DME subsystem comprises the following components:

- Wireless LAN bridge
- PC104 computer
- Yaw rate sensor
- Electronic compass
- 2 brushless DC drive motors and amplifiers
- 1 brushless DC steering motor and amplifier
- Brake system
- RF emergency brake system
- DGPS receiver

The DME computer is a PC104 computer which performs the following functions:

- Guidance, Navigation and Control (GNC) computations

- Analog and digital data input and output

◦ Inputs:

- Differential GPS information
- Electronic compass (heading angle)
- Yaw rate
- Drive motor speed
- Steering angle
- Drive motor amplifier temperature
- Drive motor winding temperature

◦ Outputs:

- Drive motor torque command
- Steer motor angle command
- Brake command

- System health monitoring

- Data collection

## DYNAMIC MOTION ELEMENT

The Dynamic Motion Element (DME), shown in [Figure 2](#), is the heart of the GST system. The DME is a completely self-contained, un-tethered, relatively high speed, mobile platform for the Soft Car, which performs all Guidance, Navigation and Control (GNC) computations, and is capable of being driven over by the subject vehicle without damage to itself or the subject vehicle.



**Figure 2. GST Dynamic Motion Element**

Positional measurements, which are the primary measurement used in the GNC computations, are achieved via the on-board DGPS receiver. Other inputs to the GNC computations include the yaw rate and heading angle, as measured by the electronic compass.

The DME incorporates a pair of brushless DC motors to drive the rear wheels, while steering of the front wheels is