Dynamic Research, Inc.

Proposal for Designation of Automated Vehicle Proving Grounds Pilot
Solicitation: DOT-OST-2016-0233

CAPABILITIES AND FACILITIES OF DYNAMIC RESEARCH, INC. FOR DESIGNATION AS USDOT AUTOMATED VEHICLE PROVING GROUND

DRI-TC-16-02

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Dynamic Research, Inc. is a Small Business
Incorporated in the State of California

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DRI OVERVIEW

Dynamic Research, Inc., (DRI) was established in 1979. It specializes in applied research, development, and consulting in the areas of vehicle dynamics, automatic and manual control, human factors, man-machine systems, driving simulator technology, biomechanics, and risk-benefit analysis. This includes analysis, simulation, and testing of automobiles, SUVs and light trucks, commercial vehicles, and other vehicles and devices. Topics addressed include driver assistance systems, automated driving systems, human factors, driver behavior, driver/vehicle interaction, vehicle dynamics and performance, control systems, biomechanics, safety, and accident data analysis. The offices and laboratories of DRI are in Torrance, California; with a proving ground and driver/vehicle test area near Bakersfield, CA. DRI is an employee owned California corporation.

A particularly pertinent area of activity at DRI has been the development and application of Standards and Guidelines related to active safety and automated driving, vehicle dynamics and performance, driver behavior, driver/vehicle interaction, and driver distraction through involvement with ISO, SAE, NHTSA, AAM, and other organizations.

DRI currently has a regular staff of 37, consisting of engineers and scientists, human factors specialists, technicians, and support personnel. They have conducted a broad range of analytical, driving simulator, simulation, system development, and driver and vehicle tests and experimental investigations, for Government agencies (e.g., NHTSA), vehicle manufacturers (e.g., Honda, GM), OEM suppliers, and other organizations.

TECHNICAL CAPABILITIES

The DRI Staff has diverse applied research skills and resources for supporting evaluations and reviews in the general areas of human factors, human-machine interaction, vehicle control systems, and vehicle

performance, as applied to ground vehicles. This includes testing and measurement of vehicle and driver system response and performance, and analyses and reviews using driving simulators and simulation.

The evaluation methods and resources used can include driver-in-the-loop simulators, vehicle testing at DRI's closed-course test site, over the road testing, analysis, simulation, laboratory studies, accident data analysis and reconstruction, and risk-benefit assessments.

Resulting measurements and response data typically include:

- Vehicle dynamic measurements, including motions of the subject vehicle and other vehicles, manual and automatic control inputs, and sensors (e.g., inertial, radar, GPS)
- Driver behavior measurements, including primary task performance and response, attentional workload, crash conflicts and imminent crashes, and secondary task activity
- Subjective assessment and ratings, including driver acceptance

The professional staff of DRI is both interdisciplinary and multidisciplinary, which are important attributes in human factor, human-machine interface, and autonomous vehicle related studies.

DRI has a Federally chartered Institutional Review Board (IRB) which is used in planning and preparing for driving simulator and actual vehicle tests with driver participants.

TEST FACILITIES AND EQUIPMENT

DRI's main office is located in Torrance, CA. Facilities at the main office include both moving and fixed based research grade driving simulators,

computer facilities, specialized laboratories, machine shop, fabrication areas, and technical library, in addition to office space and equipment.

DRI also has a vehicle test facility, located at the Minter Airport, approximately 15 miles north of Bakersfield, California. This location, in the southern portion of California's San Joaquin Valley, has weather conditions which are suitable for testing year-round with mild or warmer daytime temperatures, generally low wind, and very little rainfall. This is a private area leased by DRI for its exclusive use, which provides for confidential and uninterrupted vehicle testing. This test area is planned to be DRI's designated Automated Vehicle (AV) Proving Ground.

Originally developed for the purpose of supporting NHTSA with a year round facility for dynamic rollover (fishhook) and similar vehicle tests, the area was repaved and expanded in late 2014 to enhance its usefulness for other types of tests, including CIB and DBS procedures. The Vehicle Dynamics Area (VDA) is large, and the pavement is very high quality in terms of smoothness, levelness, and friction coefficient. As a result dynamic vehicle tests such as the NCAP rollover resistance "Fishhook" test, and the FMVSS 126 ESC Sine with Dwell test can be readily conducted. Both require a preliminary slowly increasing steer test. In addition, the run up lane allows for Lane Departure Warning and Forward Collision Warning tests to be accomplished. A variety of other driver behavior and vehicle dynamics tests have been conducted for OEMs and the Government, and this work continues. In Spring 2015 the test site was upgraded with a NHTSA specified rail and target vehicle delivery system. The upper portion of Figure 1 shows an aerial view of the test facility and the lower portion shows the current dimensions.

To support testing activities, DRI-Minter has a 1000 square foot shop with roll up doors, and adjacent 720 square feet of office space. Shop equipment includes tire mounting and alignment machines, welders, scales, lifts, etc. There is also space for secure vehicle storage.

DRI-Minter Post Repaving

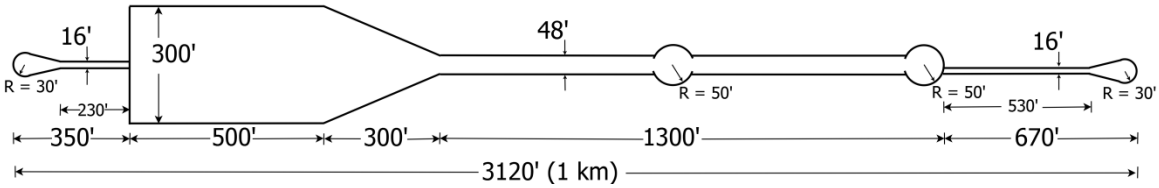

Figure 1. DRI Minter Test Facility

AUTOMATED VEHICLE PROVING GROUND PLAN SUMMARY

Every day there are many automated test vehicles driving around public roadways. However, in ordinary driving, AVs can travel hundreds, if not thousands of miles without experiencing any scenarios which pose a serious risk of collision, which we refer to as “safety critical conflict scenarios”. Safety critical conflict scenarios are by their nature rare events. Furthermore, in the relatively rare cases in which the AV does encounter a conflict scenario it is often the case that the test driver will anticipate the event and disengage the system, taking over operation of the vehicle before the AV must make critical decisions and maneuvers. This is because the driver recognizes that if the system does not react appropriately, the situation could result in damage, injury, or death.

DRI is proposing to have its Minter Test Facility become part of a network of designated proving grounds that focus on automated vehicle technology. In particular, DRI's would focus on testing automated vehicles' performance during safety critical conflict scenarios, which are difficult and often unsafe to create during real-world testing on public roadways.

DRI has developed an innovative evaluation methodology for testing conflict scenarios for AVs and vehicles with Advanced Driver Assistance Systems (ADAS). This is accomplished using the Guided Soft Target (GST) test system as illustrated in Figure 2. The GST system comprises a soft target vehicle, or Soft Car, and a programmable, autonomously guided, self-propelled Low Profile Robotic Vehicle (LPRV) as illustrated in Figure 3 and Figure 4. This system can be used to replicate the pre-crash motions of the Collision Partner (CP) in a wide variety of conflict scenarios while minimizing physical risk to both drivers and vehicles. The Soft Car is intended to be a realistic representation of a CP for the system under evaluation, and the LPRV carries the Soft Car and provides realistic CP motions.[1] In a collision between a vehicle being tested and the GST, the vehicle pushes the Soft Car off of the LPRV. The vehicle can then drive over the top of the LPRV. After the test, the Soft Car can be quickly reconstructed and placed back onto the LPRV for the next test.

Figure 2. DRI Autonomous Guided Soft Target Tests

[1] Video of the GST system being used for vehicle evaluations can be found here:
https://youtu.be/XeRUYiNjJas
https://youtu.be/bwIG0u-YMbs?t=1m32s
https://youtu.be/GA5FWrRiXJA

Figure 3. Example DRI Soft Cars

Figure 4. DRI Low Profile Robotic Vehicle (LPRV)

As a fully autonomous vehicle, the GST coordinates its motions with the subject vehicle during the pre-crash phase to replicate the initial conditions of the crash phase from run to run. At the instant that the AV 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 AV 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 impact speed, minimum distance, etc.). In addition to being an example application of autonomous vehicle technology, the GST system is a useful tool in the

assessment and compliance testing of candidate autonomous vehicles where a deficiency or failure in the AV may result in an actual crash with the CP.

The conflict scenarios are generated using a software tool called Scenario Builder. The Scenario Builder allows the user create paired time-space trajectories for the GST and the test vehicle or AV. The scenarios are then loaded onto the GST using a wireless communication link and the conflict scenario can be tested quickly, repeatably, and safely. A relatively simple example scene from the Scenario Builder software is shown in Figure 5. Any driving scenario, involving any path and any combination of steering, braking, and accelerating can be built (subject to the dynamic limitations of the test vehicle and GST system).

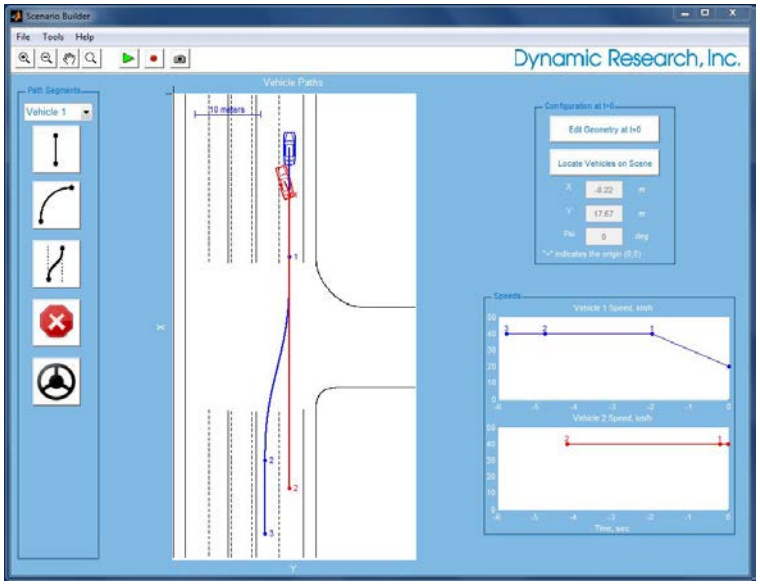

Figure 5. Scenario Builder Software

DRI is uniquely positioned to support conflict scenario testing of AVs due to its innovative GST test system, its access to a private test track that is capable of year-round testing, and our staff's experience evaluating ADAS and AV technologies.

Additionally, DRI is committed to continuously maintaining and upgrading our Minter test facility to be able to perform new tests.

DRI SUPPORT OF DOT/NHTSA TESTING

DRI has a long history of working closely with the DOT and its agencies in evaluating vehicles. Since 2006, DRI has been under contract to the NHTSA Office of Crash Avoidance Standards to conduct a variety of vehicle tests in support of its New Car Assessment Program (NCAP). These activities have included:

Rollover resistance, Fishhook test (RR), 2006 – present

Electronic Stability Control (ESC), 2007 – 2011

Lane Departure Warning (LDW), 2010 - present

Forward Collision Warning (FCW), 2010 - present

Crash Imminent Braking (CIB), 2013 - present

Dynamic Brake Support (DBS), 2013 - present

Lane Keeping Support (LKS), 2013 - present

Rearview Video System (RVS), 2013 - present

For each of these programs DRI has worked closely with NHTSA to help refine and further develop the test procedures and in the interpretation of results. In particular DRI is coordinating with NHTSA on the initial implementation of the latest test procedures for Blind Spot Detection (BSD), Pedestrian Automatic Emergency Braking (PAEB), and well as CIB, DBS, LKS and RVS.

In addition, DRI conducts verification tests for FMVSS 126, Electronic Stability Control, under contract to the NHTSA Office of Vehicle Safety

Compliance. As illustrated in Figure 6, this compliance test involves instrumenting the vehicle, installing an automatic vehicle controller (AVC), and accomplishing a series of computer controlled, programmed limit maneuvers.

The number of NCAP tests accomplished for NHTSA since 2006 is summarized in Figure 7.

Figure 6. FMVSS 126 Compliance Test for NHTSA

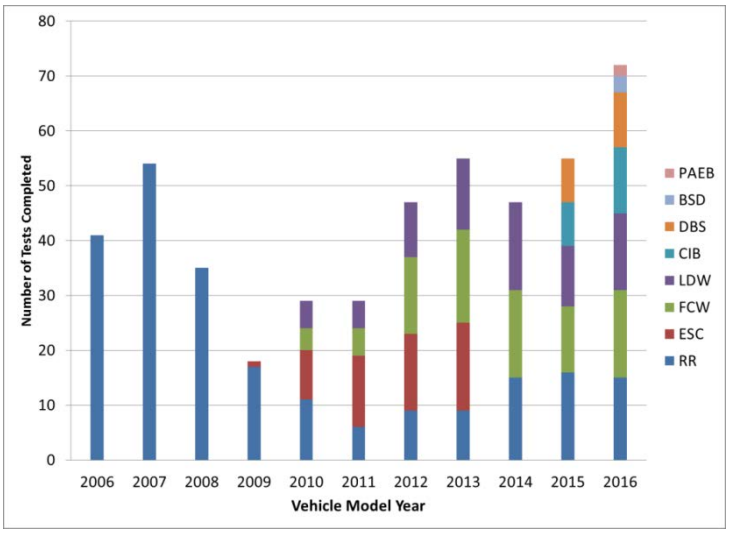

Figure 7. Summary of DRI's NHTSA NCAP Test Experience since 2006

ELIGIBILITY INFORMATION

MANDATORY CRITERIA

DRI has on ongoing commitment to safety. As such, DRI has a safety management plan in place for our Minter test facility. DRI's Designated Safety Officer is Peter Broen, who is in charge of safety at our test facility and in our shops and offices. As DRI's Designated Safety Officer, Mr. Broen will contribute and share DRI's approach to achieve a safe testing environment for AV evaluation.

PROPOSED CONTRIBUTIONS

DRI has demonstrated a long history of contributing to public safety. This typically occurs in one of two ways. First, DRI staff are active on several industry standards committees, including the SAE On Road Automated Driving committee (including the Verification and Validation task force), SAE Active Safety Systems Standards Committee, and the ISO Active Safety Working Group. In addition to committee participation, DRI has taken leadership roles in various committees. DRI staff currently chair the SAE Test Target Validation Task Force and the ISO 3D Vehicle Target Specification working group (ISO TC 22/SC 33/WG 16). Other DRI committee contributions focus on driver distraction (ISO 14198, ISO 26022, ISO 15007, ISO 12204, ISO 16673, SAE J2361, SAE J2396, SAE J2808, NHTSA Visual-Manual Driver Distraction Guidelines, and AAM Statement of Principles)

In addition to our work through industry committees, DRI also contributes through publication of research papers and presentations at various conferences. DRI has published information on its GST system and a Safety Impact Methodology (SIM) for evaluating active safety systems in the SAE International Journal of Passenger Cars. DRI has also presented research on driver distraction and workload as well as surrogate vehicle measurements at the Enhanced Safety of Vehicles (ESV) conference hosted by NHTSA.

DRI plans to continue its work of contributing to the Community of Practice as it relates to AV testing. DRI is generally willing to share procedures and data to the extent allowed by our customers or partnering organizations.

COMMITMENT TO SAFETY

DRI has a Federally chartered Institutional Review Board (IRB), DHHS Registration No. IRB00006962, which is used to protect the right and welfare of human research participants recruited in DRI applied research studies. The IRB reviews and approves all human-research-related activities that fall within its jurisdiction as specified by Federal Regulations and policies of the IRB. The DRI IRB has been established according to the guidelines of the DHHS Office for Human Research Protection and the principles and guidelines of the Belmont Report.

DRI also has developed and maintained a corporate Employee Handbook, and a Safety Policy and Procedures Manual. These documents are periodically reviewed, updated, and extend to the operations of the Minter Test Facility

RESEARCH, APPLICATION AND DATA SHARING

DRI typically disseminates research results through its work on national and international committees and through research publications and presentations. Some example publications are listed in the Appendix.

DEMONSTRATED INVESTMENTS

DRI has a record of making investments in order to facilitate improved testing. Investments in our test facility include: construction of the test track (2005), lane markings to facilitate LDW tests (2010), repaving the test track (2014), expansion of test track to accommodate higher speeds, head-on and lane change conflict scenarios (2014), and installation of a NHTSA specified rail and target vehicle delivery system (2015). Future improvements to facilitate AV testing may include additional lane markings for intersection scenarios and further expansion.

Additionally, DRI, along with NHTSA, has invested in the development of the GST test system. As this equipment can be quite expensive, DRI is one of a small number of test facilities in the world that has access to a system capable of performing conflict scenarios with an AV, and experience in its use and application.

As a private test facility, DRI does not require any special authorization to perform AV testing.

READINESS

DRI's test track has been open and operational since 2005 and has been used to test active safety systems since 2010. As is, the facility is sufficient to facilitate a large number of AV conflict scenarios. Additionally, DRI staff have experience conducting conflict scenarios with prototype AVs. The Designated Point of Contact for the test track is John Lenkeit.

DRI's test track can support multiple users and vehicles depending on the test area requirements of each user. This can often require some coordination between the test programs, which DRI staff have experience handling. The data generated during testing can be shared publicly with the permission of the customer.

ADHERENCE TO LAWS, REGULATONS, AND FEDERAL POLICY

DRI is aware of the various automated vehicle regulations at the federal and state (i.e., California Department of Motor Vehicle) level and is committed to adhere to any policies or regulations that are relevant to the testing we perform. At the current time there are no relevant regulations because DRI's test facility consists only of private roads.

APPENDIX -
SELECTED DRI-AUTHORED PUBLICATIONS

"Final Report of Forward Collision Warning Testing of a 2014 Mitsubishi Outlander," DRI-TM-13-122, Report No. OCAS-DRI-FCW-14-17, Accomplished by DRI for the National Highway Traffic Safety Administration, Office of Crash Avoidance Standards, Washington, D.C., 2013.

Kelly, J., et al., "Development of a Guided Soft Target for Crash Avoidance Technology Evaluation," SAE International Journal of Passenger Cars – Mechanical Systems 4(1):479-487, 2011.

Van Auken, R.M., et al., "Extension of the Honda-DRI Safety Impact Methodology for the NHTSA Advanced Crash Avoidance Technology (ACAT) Program and Application to the Evaluation of an Advanced Collision Mitigation Braking System - Final Results of the ACAT-I Program," SAE International Journal of Passenger Cars – Mechanical Systems 4(1):488-508, 2011.

"Advanced Crash Avoidance Technologies Program – Final Report of the Honda-DRI Team, Volume I: Executive Summary and Technical Report," DOT HS 811 454, Accomplished by Honda and DRI for the National Highway Traffic Safety Administration, Washington, D.C., 2011.

Weir, D.H. and K.C. Chao, "Development of Attentional Workload Metrics to Assess Driver Distraction," Presented at the 2nd International Conference on Driver Distraction and Inattention, Gothenburg, Sweden, September 5-7, 2011.

Weir, D.H., D.P. Chiang, and A.M. Brooks, "A Study of the Effect of Varying Visual Occlusion and Task Duration Conditions on Driver Behavior and Performance While Using A Secondary Task Human-Machine Interface," SAE 2003-0100128, March 2003.

Lenkeit, J.F., "A Servo Rider for the Automatic and Remote Path Control of a Motorcycle," SAE Technical Paper 950199, February 1995.