3D CAR TARGET FOR FUTURE VEHICLE TESTING

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ABSTRACT

Advanced Driver Assistance Systems (ADAS) and assisted and automated driving technologies are developing rapidly with more complex features constantly evolving and entering the market. These developments give rise to the need for physical testing throughout the development process and for legislative and consumer testing. With this comes the need for more advanced test devices that can be used in a multitude of scenarios to replicate a real vehicle throughout the entire manoeuvre up to the point of collision whilst maintaining a safe working environment.

The current car target test devices in use have generally fulfilled a specific purpose, for example, replicating the rear end of a vehicle. The target design and nature of their propulsion system limit manoeuvrability dictating broadly straight line or large radius turn capability only. To satisfy the future testing requirements of increasingly complex ADAS functionalities and assisted and automated driving technology for industry development, legislative and consumer test programmes NHTSA, Euro NCAP and IIHS collaborated to promote the concept and facilitate the evaluation and development of an internationally harmonised impactable 3D car target testing device.

The process comprised of the harmonising organisations liaising with test equipment suppliers and the automotive industry to evaluate candidate impactable 3D car target devices and set about a schedule of iterative development over a series of four international workshops. Industry feedback was that the DRI Soft Car 360 Fiesta offered the greatest potential for replicating a real vehicle because of its good geometrical and graphical representation and structural stability when travelling at speed. Development efforts focused chiefly on improving the radar and visual attributes of the device, culminating in ACEA and CLEPA members representing the automotive industry manufacturers and suppliers approving the final version of the DRI Soft Car 360 Fiesta as being acceptable for representing a real passenger car for automotive lidar, radar and camera sensor systems.

Subsequently, ISO has compiled a specification document for passenger vehicle 3D targets and Euro NCAP have committed to using a 3D car target meeting the ISO specification for active safety tests incorporated into the star rating from 2018 onwards.

A limitation of target requirements, the DRI Soft Car 360 Fiesta and the associated ISO specification is it leads to the device resembling a B segment hatchback vehicle. This type of vehicle is common amongst the European fleet, however other vehicle types such as pick-ups and saloons are prevalent in other developed territories. Although the body shape, size and ride height varies substantially between these vehicle types, they all possess certain similar features as a result of general vehicle design and construction and legislative requirements. Therefore, whilst not wholly representative of all the different vehicle types and constructions, the 3D car target as specified serves as a useful device for testing purposes harmonised across notable testing organisations around the world.

INTRODUCTION

Advanced Driver Assistance Systems (ADAS) and assisted and automated driving technologies are developing rapidly with more complex features constantly evolving and entering the market. These developments give rise to the need for physical testing throughout the development process and for legislative and consumer testing. With this comes the need for more advanced test devices that can be used in a multitude of scenarios to replicate a real vehicle throughout the entire manoeuvre up to the point of collision whilst maintaining a safe working environment.

This paper describes the limitations of current car target test devices, and the process of identifying, evaluating and developing the attributes of an impactable 3D car target that can be used for the more complex vehicle testing scenarios of the future. An ISO standard specifying the attributes of the target has been compiled and the limitations of the devices is also acknowledged.

LIMITATIONS OF CURRENT CAR TARGETS

The need for target devices to support the development and assessment of Advanced Driver Assistance Systems (ADAS) has led to numerous vehicle target designs of various constructions. Some have been developed in support of particular test regimes, for example the Euro NCAP Vehicle Target (EVT) (see Figure 1) or the NHTSA Strikeable Surrogate Vehicle (SSV) (see Figure 2), whilst others have served specific development purposes such as inflatable balloon cars or silhouettes supported alongside carrier vehicles. These target devices have often fulfilled a specific purpose, for example replicating the rear end of a vehicle, albeit via different engineering solutions. The target design and nature of their propulsion system – typically a towed rail-like device affording scope for travel post impact – limit manoeuvrability dictating broadly straight line or large radius turn capability only.

The development of more complex ADAS technologies and the advent of autonomous driving gives rise to the demand for more car-fidelic solutions providing a whole vehicle representation that can be used in numerous test scenarios. Starting afresh also provides the opportunity for international harmonisation amongst testing regimes, benefitting society by hastening the

Figure 1. Euro NCAP Vehicle Target (EVT)

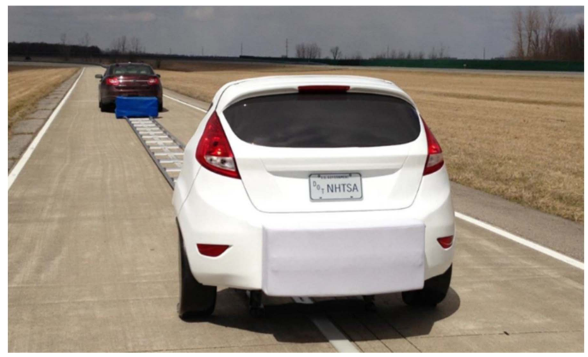

Figure 2. NHTSA Strikeable Surrogate Vehicle (SSV)

industrial development and deployment of systems onto the market because of the reduced confirmation test workload. However, a benefit of multiple test devices being used internationally is the potential system robustness engendered resulting in greater real world benefit.

DEVELOPMENT AIMS AND OBJECTIVES

The aims of developing a new 3D car test target were to:

- Achieve an appropriate full perimeter attribute representation of a typical B or C segment small passenger car for typical current and future automotive sensors (camera, radar and lidar)
- Develop a device suitable for both stationary and dynamic testing with appropriate stability during high speed manoeuvring.
- Provide impactability at typical testing speeds causing minimal cosmetic damage

to the test vehicle, and be rebuildable whilst maintaining durability of attributes.
- Be compatible with multiple propulsion devices.

The desired attributes led to often conflicting requirements, for example the necessity for stability when travelling at speed versus impactability with minimal damage, or appropriate complex vehicle attributes yet impactable whilst maintaining said attributes.

In order to facilitate a harmonised approach amongst major testing organisations Euro NCAP, the National Highway Traffic Safety Administration (NHTSA) and the Insurance Institute for Highway Safety (IIHS) worked in collaboration to:

- Promote the concept of an internationally harmonised impactable 3D car target testing device to industry stakeholders.
- Facilitate the assembly of candidate target devices for evaluation by the automotive industry.
- Provide a means for industry to feedback objective assessment of the candidate devices.
- Set out gateways for an iterative process to develop and confirm finalised device(s).

DEVELOPMENT PROCESS

The first event, assembling candidate 3D car target devices for initial evaluation, was hosted by Thatcham Research on behalf of Euro NCAP in July 2015. The aim of this event was to kick start the development process by assembling stakeholders including the harmonising institutions to illustrate the need for such a device, and the automotive manufacturer and supplier representatives and the candidate 3D car target devices for preliminary device evaluation. Dynamic Research Inc. (DRI) attended with their prototype Soft Car 360 targets in two formats, a foam panel construction vehicle broadly representing a Ford Fiesta (see Figure 3) and a Smart fortwo (see Figure 4). Dr. Steffan Datentechnik (DSD) brought their air tube construction target with a vehicle cloak broadly representative of a Mercedes C-Class (see figure 5). Two propulsion systems were also in attendance: Anthony Best Dynamics (ABD) provided their Guided Soft Target (GST) platform and DSD brought their Ultraflat Overrunable Robot (UFO) platform. A real Ford Fiesta was also provided for reference measurement purposes.

Figure 3. DRI Soft Car 360 Fiesta – development version

Figure 4. DRI Soft Car 360 Smart

Figure 5. DSD saloon car target

Fifteen vehicle manufacturers and suppliers were represented at the two day event. Testing comprised of straight line approaches towards various target and platform combinations oriented at various angles in order to evaluate the perimeter representations. A limited amount of testing was also completed with moving target and platform combinations assessing them from the front and rear and in a crossing situation. Attendees completed a feedback form subjectively rating the various target and platform combinations for their radar and visual attributes based on their individual objective assessments, classified thus:

- Good – Good representation of a real vehicle that requires no further development.
- Acceptable – Acceptable representation of a real vehicle however would benefit from further development.
- Poor – Unacceptable representation of a real vehicle requiring further development.

These ratings, combined with illustrative comments, were anonymised and combined in order to provide an overview of the current status of targets and their potential future suitability.

The feedback suggested that regarding radar attributes, all platform and target combinations required improvement in order to represent a real vehicle, specifically regarding the target generating the radar return rather than the carrier platform. Visually, the DRI foam panel style construction offered a better representation of a real vehicle than the DSD air tube and cloak because of the structural rigidity and surface stability, especially when moving. Visual characteristics that required improvement in order to replicate a real vehicle included graphical alignment, adding a prominent interior view, hiding or disguising the propulsion platform, improving the wheel and tyre representation and minimising surface wrinkling.

Based on the industry feedback and the potential to address the technical issues raised, the DRI Soft Car 360 was selected as the focus for future development efforts to engineer the first vehicle target example. The Fiesta model was chosen because of its general representativeness of the global car fleet in terms of shape and features coupled with its smaller size lending itself more appropriately to developing a manageable device regarding the practicalities of testing, chiefly impactability and reconstruction.

Acknowledging feedback concerning the visual and radar attributes, DRI developed a revised Soft car 360 Fiesta including increased areas of radar

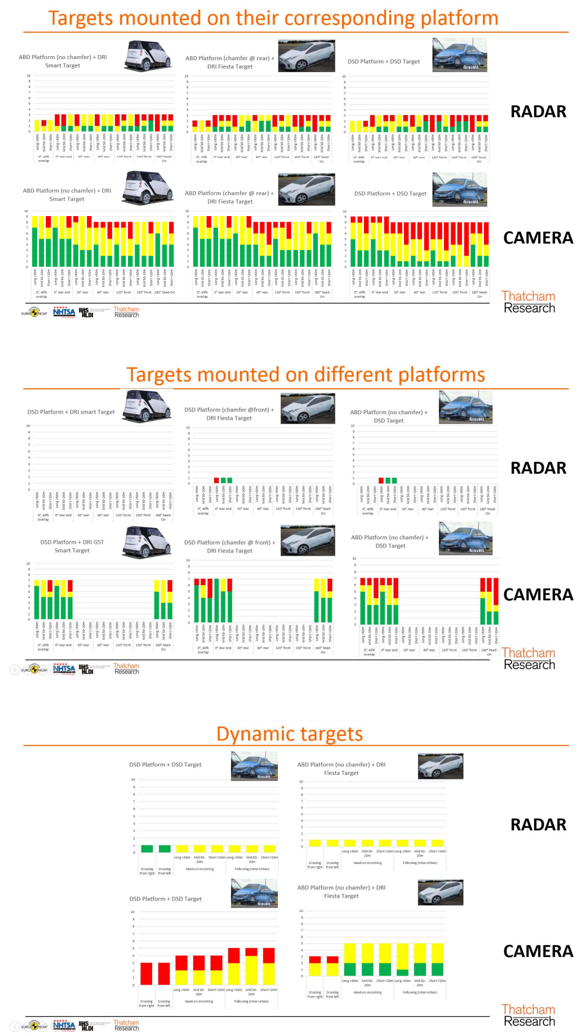

Figure 6. Summary of industry feedback from first event

reflective material, revised graphics, surface stiffeners and wheel blocks and brought it to the second two day event, also hosted by Thatcham Research on behalf of Euro NCAP in the UK in April 2016. A similar group of automotive industry manufacturers and suppliers attended, and it was quickly identified that although the revisions had improved the overall visual and radar representation, there was a significant issue with high power internal radar reflections returning from within the target when approaching it from the rear.

Although returns from within the length of the vehicle are entirely feasible and often seen with real vehicles, the highest power return typically originates from the region of the rear of the body whilst lower returns are reflected by the underbody, axles, powertrain and exhaust systems etc. According to the radar return analysis algorithms, the target reflection manifested itself as a queue of vehicle rear ends, albeit at separations implausible for real vehicles, leading to confusion locating the position of the rear end of the target. Various configurations of radar reflecting and absorbing materials and were trialled to treat the issue, the most successful being to enclose the vehicle body down to the platform with radar reflecting material at the axle position.

These field modifications were incorporated into another generation of the Soft Car 360, along with the door mirrors, for a third two day evaluation workshop hosted by NHTSA in the United States in July 2016. Feedback at this stage deemed the visual attributes of the target as being acceptable, however the issue of internal reflections remained sufficiently causing problems identifying and classifying the position of the target. At this stage numerous treatments were once again trialled, however a satisfactory solution was not identified given the limited materials and analysis capability at the test track.

It was at this stage that three tier one suppliers offered to work directly with DRI to investigate the issue and identify potential target modifications and treatments on a one-to-one basis with additional analysis capability to hand. This process, which took place in August 2016 first in Ohio and then in California, attended to the problem by altering the way in which the radar reflective material closed off the internal structure of the target in the bulkheads against the platform at the front and rear, whilst absorbing material in the side skirts shielded the area between the axles. The suppliers also completed additional radar measurements from various angles confirming the radar attributes around the full perimeter of the target.

This final version of the Soft Car 360 Fiesta (see Figure 7) was presented at a confirmation event hosted by AstaZero on behalf of Euro NCAP in Sweden in November 2016. Minor modifications included tell tale markings to identify incorrect cover panel alignment and additional radar reflective material in the front windscreen area. Two identical examples of the target were provided for comparative evaluation purposes by the industry manufacturer and supplier attendees. They were evaluated in both stationary and moving scenarios approaching from various angles driving directly towards and also passing by alongside. Consolidated feedback provided by members of the European Automobile Manufacturers (ACEA) and the European Association of Automotive Suppliers (CLEPA) approved the target as being acceptable for representing a real passenger car for automotive lidar, radar and camera sensor systems.

Figure 7. DRI Soft Car 360 Fiesta – final version

TARGET SPECIFICATION

Once the design of the device was finalised the International Organisation for Standardisation (ISO) set about compiling a specification document for passenger vehicle 3D targets. ISO 19602 Part 1 (ISO, 2017) specifies the properties of an omni-directional multi-purpose vehicle target that will allow it to represent a passenger vehicle in terms of size, shape, reflection properties, etc. for testing purposes.

The document addresses the attribute detection requirements for a vehicle target in terms of sensing technologies commonly in use at the time of publication of this standard, and where possible, anticipated future sensing technologies. It also addresses methodologies to verify the target response properties to these sensors, as well as performance requirements for the target carrier.

The specifications were determined with input from DRI detailing the dimensional and graphical attributes of the final version of the Soft Car 360 Fiesta verified by the automotive industry, and Radar Cross Section (RCS) corridors supplied by NHTSA via testing carried out on their behalf by the Michigan Technical Research Institute.

It is important to stress that future consumer test programmes will specify the use of a target in accordance with the specification rather than mandating a specific device manufactured by a particular supplier.

At the time of writing, agreements are being finalised for the Soft Car 360 Fiesta to be manufactured under licence and distributed locally to serve the market demand and provide technical support and spare parts. Alternative devices meeting the specification are known to be in development by 4activeSystems GmbH and Moshon Data amongst other organisations.

INTENDED USES

Euro NCAP have committed to using a 3D car target meeting the ISO specification for active safety tests incorporated into the star rating from 2018 onwards. These tests include Autonomous Emergency Braking (AEB) front-to-rear with full and partial overlap scenarios and Emergency Lane Keeping (ELK) assessments for collision scenarios with oncoming and overtaking vehicles, necessitating the use of vehicle surrogate that wholly represents a real vehicle with full a perimeter representation. In order to standardise testing, 3D car targets could also be used for the vehicles parked at the side of the test for the obscured child pedestrian crossing AEB test scenario.

Future Euro NCAP testing will see 3D car targets used for assessing junction collision avoidance technologies in scenarios such as turning across path of another vehicle and perpendicular crossing vehicles. RCAR have committed to using 3D car targets meeting the ISO specification for insurer relevant active safety testing of technologies including frontal AEB for front-to-rear crashes and reverse AEB for parking and low speed manoeuvring collisions.

Essentially any real world car collision type can be replicated with the 3D car target as one of the impact partners in order to prove out the performance of active safety features that may function to mitigate or avoid the collision. It could also be used to investigate driver responses to rapidly developing collision situations in a safe fashion.

The advent of assisted and automated driving technology gives rise to a wide range of development, legislative and consumer testing requirements, at least some of which will require real world testing in near miss scenarios with replicative yet impactable car targets in order maintain a safe working environment whilst evaluating the systems. In the near term, technologies such as highway driving assistance could be assessed using 3D car targets, particularly critical manoeuvres in which the vehicle has to deal with imminent collision scenarios or where a short notice driver takeover request is issued. Regarding automated and remote control parking and longer term automated driving technology, 3D car targets could be used as other 'real' vehicles throughout the development process to confirm simulation results eliminating the potential for vehicle damage.

3D car targets could also be used for demonstrating active safety technology and educating the public at events, allowing them to drive for themselves and experience the technology intervening in critical situations, thus adding realism to the situation.

LIMITATIONS

The desirable attributes of the 3D car target often led to conflicting requirements, and an improvement in one feature was often realised at the detriment of another. Therefore the final design balances the necessary compromises, erring towards the fidelity of replicating a real vehicle. An example of this on the DRI Soft Car 360 Fiesta is the body stiffening blocks and ribs and the wheel blocks, which given the desired impactable nature of the vehicle would ideally be as small and soft as possible, however in order to achieve the required attributes they had to be incorporated.

The target specification leads to the device resembling a B segment hatchback vehicle, a type common to the European fleet. However other vehicle types are also prevalent in other developed territories, for example the pick-up in US and Australia, the saloon in Asian markets generally and the mini-van in Japan. Although the body shape, size and ride height varies substantially between these vehicle types, they all possess certain similar features as a result of general vehicle design and construction and legislative requirements, namely a body structure supported by wheels located towards the extremities that extend to meet the paved surface, a gap and shadow underneath the body, symmetrical lighting installations, a licence plate, horizontal feature lines etc. Commercial and passenger service vehicles, although on a difference scale geometry wise and tending towards different construction techniques, also possess similar features. Therefore, whilst not wholly representative of all the different vehicle types and constructions on the market, the 3D car target as specified serves as a useful device for testing purposes harmonised across major testing institutions.

The requirement for 3D car target to be propelled, typically via motorised platform solution, compromises the area under the target compared to a real vehicle, where normally there would be free space and a shadow. On the DRI Soft Car 360 Fiesta some free space is afforded under the front and rear sections, and from the sides a non-reflective skirt material serves to provide a contrasting area to the body replicating the shadow.

A constant challenge to the harmonising organisations and device suppliers throughout the development process was the need to minimise the reconstruction time post impact whilst incorporating the necessary attributes. With the DRI Soft Car 360 Fiesta this was achieved to a limited extent by modifying the design to reduce the component count where possible. It remains an opportunity to suppliers to develop a device that achieves the attributes in the ISO specification, maintains impactability and optimises the reconstruction time.

The Euro NCAP implementation target of January 2018 focused and hastened the development process, especially the intention to provide the automotive industry with one year between a device being finalised and official testing commencing. As a result of exceptional industry support and commitment this timeline was achieved and the design was frozen late 2016 and the specification developed shortly after. It is acknowledged that because of sensor technology and interpretation algorithm developments new target attribute requirements may develop in time. This, combined with experience gained during operation and testing regarding repeatability and degradation with repeated impacts, may lead to future generations of targets meeting revised specifications, however for now they will remain fixed until at least 2020 and specific issues will be handled on a case-by-case basis and details recorded for future reference.

CONCLUSIONS

To satisfy the future testing requirements of increasingly complex ADAS functionalities and assisted and automated driving technology for industry development and legislative and consumer test programmes NHTSA, Euro NCAP and IIHS collaborated to promote the concept of an internationally harmonised impactable 3D car target testing device and facilitate the assessment and development of candidate devices by the automotive industry.

The process comprised of the harmonising organisations inviting test equipment suppliers to assemble their candidate 3D car target devices at a workshop for initial evaluation by the automotive industry. DRI and DSD supplied their prototype devices and the industry feedback was that the DRI Soft Car 360 Fiesta offered the greatest potential for replicating a real vehicle because of its good geometrical and graphical representation and structural stability when travelling at speed.

Over a series of three workshop events, development efforts focused chiefly on improving the radar attributes to increase the overall RCS of the target, minimize that of the carrier platform and eradicate spurious internal reflections. Visual improvements included a number of more subtle changes such as improving the graphical alignment, minimising surface wrinkling and adding more prominent features and wheels. This culminated in ACEA and CLEPA members representing the automotive industry manufacturers and suppliers approving the final version of the DRI Soft Car 360 Fiesta as being acceptable for representing a real passenger car for automotive lidar, radar and camera sensor systems.

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A limitation of target requirements, the DRI Soft Car 360 Fiesta and the associated ISO specification is it leads to the device resembling a B segment hatchback vehicle. This type of vehicle is common amongst the European fleet, however other vehicle types such as pick-ups and saloons are prevalent in other developed territories. Although the body shape, size and ride height varies substantially between these vehicle types, they all possess certain similar features as a result of general vehicle design and construction and legislative requirements. Therefore, whilst not wholly representative of all the different vehicle types and constructions, the 3D car target as specified serves as a useful device for testing purposes harmonised across notable testing organisations around the world.