# A STUDY OF US CRASH STATISTICS FROM AUTOMATED CRASH NOTIFICATION DATA

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## ABSTRACT

This paper analyzes data available as part of telematics-based automatic collision notification in vehicles so equipped for all cases of frontal impact that generated the collision notification. Such data are transmitted as part of collision notification system and intended to enhance the effectiveness of emergency services in providing timely and appropriate care to vehicle occupants. Only the information related to vehicle kinematics is used for the present study and any information that may uniquely identify vehicle customers was removed.

The correct values of maximum velocity change during these crashes are presented here. It was also possible from this data to generate estimates of the time period over which these velocity changes occurred. Since injury parameters measured in tests are related to the rate of dissipation of the vehicle's kinetic energy, the availability of the information regarding the time period for maximum velocity change greatly enhances the value of crash data in defining crashes and thus in setting research priorities for improving traffic safety.

## INTRODUCTION

Knowledge of parameters defining automobile crashes is of great significance in developing priorities and countermeasures for reducing societal harm associated with such crashes. Historically, in order to generate such information, motor vehicle safety researchers examined selected vehicles involved in crashes, measured residual deformation patterns, applied conventional modeling techniques along with known algorithms and calculated various collision parameters such as dissipated kinetic energy, post-collision vehicle motion and change in velocity. Such post-crash reconstructions are known to be limited in terms both of the amount of information that can be generated as well as the precision of the results. For example, crashes are quantified by estimates of maximum change in vehicle's velocity (ΔV) by these techniques. It is shown in this paper that it is possible to obtain a more complete and accurate description of crashes by using the limited data used by a telematics-based advanced automatic crash notification system (AACN).

The capability to automatically provide information about a crash to a central source was introduced by OnStar several years ago. This system, known as ACN, uses airbag sensors in the car along with a GPS system to determine the car location and notifies an operator when an airbag is deployed. The operator, in turn, contacts emergency services to get proper services to respond to the vehicle crash.

The Advanced Automatic Crash Notification (AACN) system was introduced by OnStar in General Motors vehicles to further improve the existing capabilities of the automatic airbag deployment notification system [1]. This AACN system provides an automatic call to the OnStar Center when any of the following occur during a crash:
a) an airbag is deployed;
b) maximum change in velocity (ΔV) of the vehicle exceeds pre-determined crash severity criteria;
c) a vehicle rollover is detected by a rollover sensor.

The AACN system thus enhances the capability of the previous system by also providing notifications in other types of crashes where a possibility of significant injury may exist.

In this paper, AACN data for the period from May 2005 to May 2006 are utilized for study of front impact crashes. These crashes are divided into two categories – (a) those with airbag deployment and, (b) those where the crash severity was not sufficient to deploy airbags but exceeded a predetermined maximum change in velocity (ΔV). The cases corresponding to condition 'b' are referred to as 'non deployment' cases in this paper.

The determination of ΔV of the vehicle is made from crash sensors which are present in the vehicle for deployment of restraint systems (e.g. airbags, seatbelt pretensioners, etc). These sensors usually measure acceleration of the vehicle and ΔV is obtained by integration of the acceleration, beginning from the instant a crash is determined by pre-programmed algorithms. For purposes of AACN and for getting an indication of crash severity for communication to emergency services, the maximum change in velocity (ΔV) calculated from the vehicle crash sensors is utilized. The vehicle velocity is calculated during a 300 millisecond window with 15 discrete data points each separated by 20 milliseconds. For deployment events, three ΔV samples are taken prior to deployment, one sample is approximately at deployment and eleven samples are after deployment. For non-deployment events, the ΔV samples start at the time the impact is detected. Since there are sensors present for longitudinal as well as for lateral impacts, estimates of ΔV are available in all crash directions. In addition, an estimate of the direction of impact is made from the x- and y-components of ΔV.

It should be noted here that the AACN system uses the acceleration records in the sensing and diagnostic module (SDM) in the vehicle and the calculated ΔV approximates the change in velocity at the center of gravity of the vehicle. Other accelerometers that may be present for detection of localized impacts (e.g. front sensors mounted near the radiator front) are not utilized in the calculation of ΔV in the present study, although they are utilized in determining the deployment of restraints in the automobile.

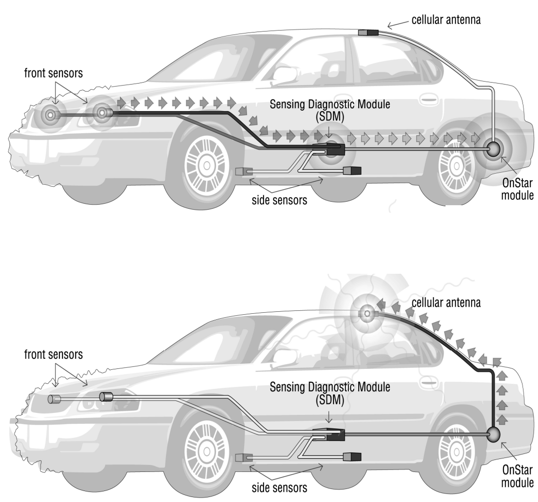


**Figure 1: Schematic Representation of AACN System**

In the event of a front-, rear- or side-impact crash exceeding the crash severity criteria, the SDM transmits crash information to the vehicle's OnStar module. In cases of rollover, the rollover sensor also provides the data for transmission to OnStar. The following data are transmitted:
a) Identification of the deployed airbag and if any were suppressed because of suppression systems;
b) Identification of a non-deployment event meeting or exceeding crash severity criteria;
c) Maximum change in velocity (ΔV) of the vehicle and the time step at which this occurs (if the maximum ΔV occurs later than the above-mentioned window of 300 milliseconds, its value is transmitted but the time step count remains at 15);
d) The principle direction of impact at maximum ΔV;
e) Identification of a vehicle rollover when rollover sensors are present;
f) Identification of single or multiple impacts if they occur within the 300 millisecond window.

Upon receipt of this crash information, the OnStar module sends a signal to OnStar Center through a cellular connection, informing the advisor that a crash has occurred. A voice connection between the OnStar advisor and the vehicle occupant is established and the advisor can then contact the appropriate emergency services (e.g. ambulance, rescue, etc) and provide these with crash information that can help estimate the severity of the crash and determine the appropriate rescue and medical services. This pre-determination of likely crash severity and direction of impact, as well as vehicle location determined by GPS system (as part of OnStar system), may help reduce the time taken for appropriate response as well as for the readiness of appropriate medical care. Previous studies [2, 3] have shown that the time taken from the moment of injury to the administration of medical care in the proper facility is a critical factor in determining post-crash outcome for the automobile occupant and the AACN system may provide a significant reduction in this total time taken.

The present study is based only on the above-mentioned transmitted records from the selected crashes and does not contain other data about the vehicle or its occupants. Although the data utilized in this study are a subset of those studied elsewhere [4, 5], the large number of cases that can be included in the present methodology provide a wider perspective than is possible from smaller sample sizes.

## ANALYSIS OF AACN DATA FOR FRONT IMPACTS

For the present study, vehicle-related data from frontal crashes with AACN notifications from May 2005 to May 2006 was analyzed. During this period, there were 1045 recorded frontal crashes with frontal airbag deployment in the AACN-equipped vehicles. In addition, there were 356 cases of 'non deployment' frontal crashes where the predetermined thresholds for AACN in frontal impact were reached or exceeded. For these events, the maximum changes in velocity (ΔV) were analyzed as follows.

For each of the 1045 events of frontal impact accompanied by deployment of one or both front airbags, the maximum change in velocity (ΔV) is shown in Figure 2.

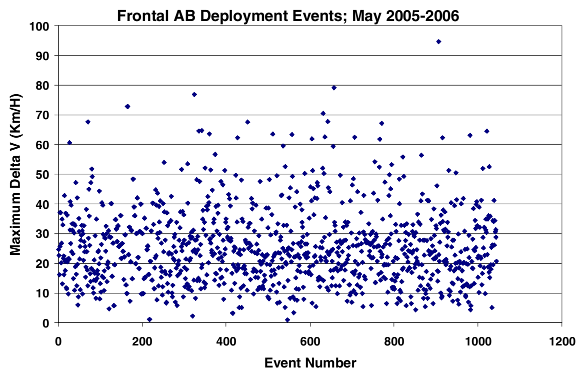


**Figure 2: Maximum ΔV for Frontal Crashes with Airbag Deployment**

It is observed that maximum ΔV in these crashes has a wide distribution, with most of the cases being below 40 kilometers per hour. The frequency distribution of ΔV is shown in Figure 3, indicating that 95% of these crashes have maximum velocity change of less than 50 kilometers per hour.

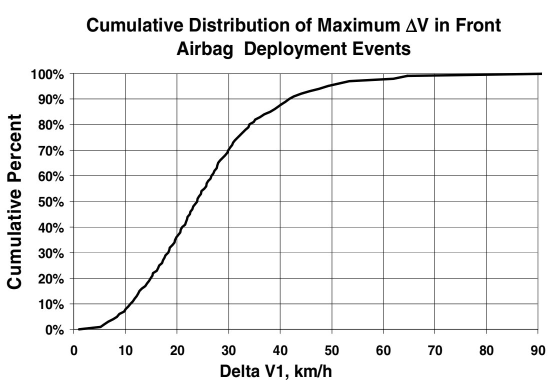


**Figure 3: Distribution of Maximum ΔV in Front Crashes with Airbag Deployment**

The maximum change in velocity in the 356 cases of 'non deployment' in front impacts is shown in Figure 4. It is observed that these ΔV values are bounded at the lower end by the AACN deployment threshold set for the system.

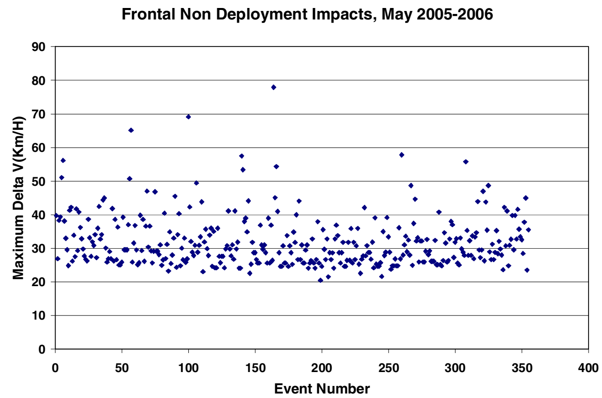


**Figure 4: Maximum ΔV for Frontal Non-Deployment' Events**

**Definition of Crash Severity for Front Impacts**

In existing literature, statistical information on crash severity has been presented as estimates of maximum velocity change during the crash, without any estimates of the time period over which such velocity changes occur. This lack of information about time period is due to the fact that accident reconstruction techniques utilized by researchers for post-crash investigation are capable of generating only limited information with some degree of reliability. This knowledge of maximum change in velocity provides information of the pre-impact kinetic energy of the vehicle dissipated during the impact but not about the rate of such energy dissipation.

However, as is well understood, the probability of injury during an impact is proportional not to the energy dissipated but to the rate at which energy is dissipated (defined as mechanical 'power'). This is illustrated by two simple examples of considering a moving body traveling at a given initial velocity and impacting two different surfaces – one being a stiff surface with little energy dissipation and the other being a soft surface with significant energy dissipation. An example of the first type of surface would be a thick steel plate and an example of the second type would be expanded metal honeycomb of low stiffness. The injury suffered by the moving body impacting a hard surface with little energy dissipation capability is likely to be of much higher severity than the same body impacting a softer surface with significant energy dissipation, all other variables being the same in both impacts.

As another example, a crash of a certain ΔV over a longer duration (for example, an impact into a soft embankment) is of lower severity (less likely to cause injuries) than another crash with the same ΔV in a shorter duration (e.g. an impact into a rigid barrier).

The relationship between injury probability and the rate of energy dissipation can be expressed as the functional relationship:

***Injury Probability*** $\alpha$ ***Rate of Energy Dissipation***

Therefore, defining crash severity by only the maximum ΔV value is not likely to reliably estimate the injury probability in the crash. It is therefore highly desirable that crashes be described not just by the maximum ΔV but also by the duration over which this velocity change occurred in the crash. Such information is available when detailed time history of the crash event is obtained [4] from devices such as the data recorders available in some vehicles.

This detailed velocity-versus-time record in crashes was not available for the present study (since it is not part of the data utilized in AACN transmission) and therefore, an attempt is made here to estimate these from the available data. As described earlier, the transmitted data provides 15 values of ΔV every 20 milliseconds arranged such that the first three values of ΔV are prior to the event (airbag deployment or AACN deployment) and 12 samples are after the event (in the case that the maximum ΔV in the crash occurs later than 12 time steps from the deployment, the maximum ΔV is available but the time step count stops at 15 as described above). Thus, each value of ΔV is associated with a counter which enables the estimation of time duration from airbag or AACN deployment to the maximum ΔV in the crash. This distribution of maximum ΔV and the time calculated for all the front crashes with front airbag deployment is shown in Figure 5.

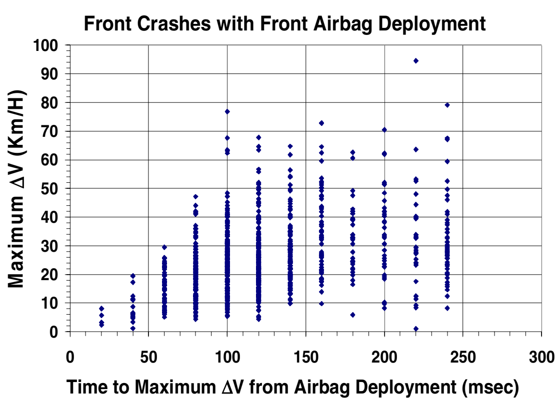


**Figure 5: Maximum ΔV versus Time in Front Crashes with Airbag Deployment**

To compare this data from field events to similar data from crash tests, the velocity versus time plot from a 64 kilometer/hour front impact test against a rigid barrier (US NCAP test) is shown in Figure 6. The maximum ΔV in such tests is usually higher than the nominal test speed due to the 'rebound' of the vehicle during the test (approximately 5 to 10 km/h).

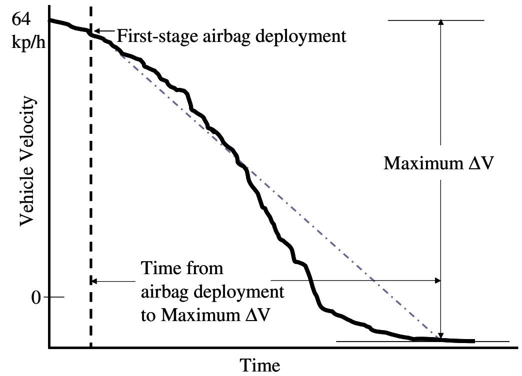


**Figure 6: Vehicle Velocity versus Time in 64 km/h front rigid barrier impact**

Front airbag sensing systems are designed to predict crash severity in time to inflate airbags and restrain the occupants, and a 'typical' ΔV associated with the airbag deployment command in the above test (64 km/h front impact into a rigid barrier) may be at 4-8 km/h (this is dependent on the vehicle and is likely to be somewhat different for each vehicle depending on design parameters).

It is then possible to compare the severity of frontal crashes observed in the field to that in existing tests such as the one described above. In order to do this, NCAP test data for the vehicle groups in the AACN

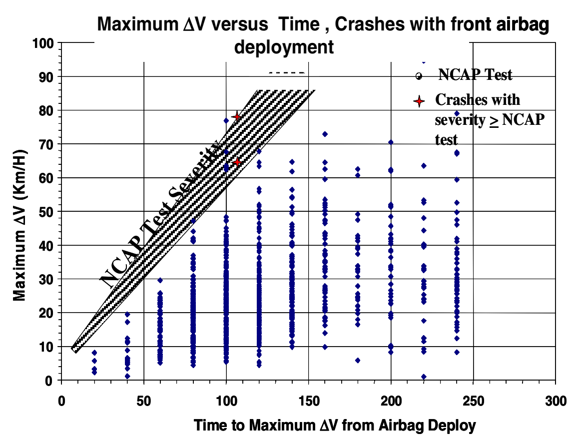


**Figure 7: Comparison of Front Crashes with Airbag Deployment to 56 km/h NCAP Tests**

data set were analyzed to obtain the time and the value of maximum ΔV as well as the time and the ΔV of front airbag deployment. This ‘corridor’ of crash severity for NCAP tests is shown in Figure 7. Also shown in this figure are crashes where the crash severity would meet or exceed the NCAP test severity of the corresponding vehicle showing only two cases whose crash severity as measured by the averaged deceleration would meet or exceed the severity of the NCAP tests.

A similar evaluation was done to compare the severity of the 1045 frontal crashes with airbag deployment to the crash severity of front offset crashes into a deformable barrier with an impact speed of 64 km/h. The calculated severity of the offset deformable barrier tests for the same family of vehicles is shown in Figure 8 along with those crashes in the field whose severity (as defined by the ‘averaged’ severity described above)

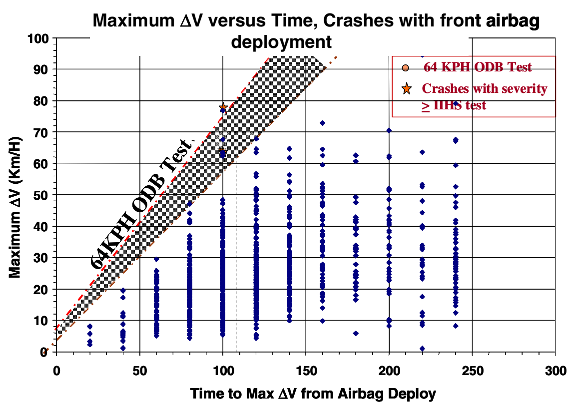


**Figure 8: Comparison of Front Crashes with Airbag Deployment to 64 km/h ODB tests**

would meet or exceed that of the severity of the 64 km/h offset deformable barrier test for the corresponding vehicle. It is noted that there are only two such crashes among the 1045 frontal impacts in the crash database of frontal impacts with airbag deployment.

## CONCLUSIONS

A methodology for obtaining crash statistics from advanced automated crash notification (AACN) data has been described in this paper. With this methodology, it is possible to obtain correct values of maximum ΔV as well as estimates of the time scale associated with the ΔV in a crash. Data for the correct direction of impact (principal direction of force) are also available but are not shown here. Results have been presented for front crashes with airbag deployment as well for front crashes without airbag deployment but with maximum ΔV exceeding predetermined values. Almost all (99.8%) of the front airbag deployment crashes observed were less severe (based on averaged deceleration) than the 56 km/h NCAP test and the 64 km/h ODB test, two of the front impact tests currently used in the US to assess and rate vehicle crashworthiness. It is also observed that large number of crashes occur with lower values of maximum ΔV and over longer time durations.

The significance of the present study is that all crashes of vehicles equipped with AACN or similar systems can be analyzed without need for detailed investigations and that crash severity can be obtained in terms of velocity change, associated time duration as well as direction of impact (not presented here). Such enhanced description of crashes by a complete set of parameters relevant to injuries is important since it provides a better description of the field conditions than is possible by classical methods and is therefore valuable in setting research priorities for improvement of automotive safety.

## ACKNOWLEDGEMENT

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