Alliance Research Project ñ Field Data Collection and Analysis for Evaluation of Inflatable Restraint Performance

Don Bischoff
Consultant to Alliance of Automobile Manufacturers

I. Introduction\Background

A. General comments on Alliance one pager describing the research project (see Appendix A for copy of paper).

- First of all, I think the name (Unbelted Occupant Evaluation in High Severity Crash Events, Field Data Collection and Analysis) and focus is wrong. In order to make a judgment about the optimal power level for air bags you need to look at both belted and unbelted crashes. There are compromises that the restraint engineer needs to make in attempting to provide optimal protection to all classes and sizes of occupants. By restricting the data collection to only unbelted occupants you will get only half the story. Granted, I believe that most of the expected change in effectiveness (if there is any change) will come for the unrestrained occupants. However, I believe that we also need to know what the effects are for the belted occupants to understand the overall effectiveness of second-generation air bag systems.

- The notion of using the Insurance Industry to establish a crash notification process has been tried in the past without much success. State Farm is the only insurance company that has the ability to even discriminate crashes by the parameters of interest (make/model of vehicle and severity of the crash). NHTSA and the auto industry set up a notification protocol with State Farm for their Special Crash Investigations (SCI) of air bag performance evaluation. The notifications were apparently not timely enough for the SCI team members to gather the necessary data (vehicles were already repaired or disposed of, occupants could not be found for interview, etc.). Chip Chidester, NHTSAís person in charge of SCI investigations, advises that not a single NHTSA SCI crash investigation was initiated as a result of the State Farm notifications.

  I spoke with Charlie Sollars and Sam Boyden of State Farm in an attempt to understand what went wrong with the previous effort and whether changes could be made to improve the timeliness of notification. The prior effort used a list of VINs supplied by the auto industry to run a ìtrapî of crashes that involved air bag equipped vehicles of interest. This process resulted in notification of the State Farm home office within 1 or 2 days of a relevant crash being reported to a local State Farm agent. The State Farm home office then sent an email to the agent explaining the research program and asking the agent to obtain written authorization from the insured to release the crash information to the research crash investigation team. This is where the system apparently broke down; the written authorizations were not returned in a timely manner and it was thus not possible to notify the crash investigation teams in a timely manner.

State Farm is currently sponsoring a research project at Childrenís Hospital in Philadelphia, PA, that has a crash investigation component. The legal department at State Farm has arranged for the use of verbal authorizations for this project. The study is limited to specific geographic regions and the State Farm agents in these areas have received extensive training on the research program and the notification protocol. The verbal authorization procedure and training regimen have reduced the lag time to notification of the crash investigation team.

State Farm staff said they would consider approaching senior management with a proposal for future cooperative efforts with NHTSA and the auto industry if the design of the program could be specified. The program would likely need to be severely limited in geographic area and training of agents would need to be accomplished following the Childrenís Hospital model. With these restrictions, I do not see much benefit over the notification systems that are currently in place for special crash investigations.

- We can certainly coordinate with the CIREN centers to gather anecdotal data on air bag system performance, but as will be discussed later in the paper, I do not see the CIREN teams as the optimal way to gather field performance data that will address the questions that we are trying to answer.

B. Options Explored In This Paper for Gathering Additional Crash Data

One can imagine that that there are many options for gathering crash data. In this paper, the following 7 options were explored:

1. Wring more relevant crashes (late model year, high severity) out of the existing National Automotive Sampling System (NASS).
2. Expand the existing NASS system so that it has the capability to investigate more of the relevant crashes.
3. Utilize the existing NHTSA SCI teams.
4. Utilize the existing CIREN centers.
5. Utilize existing Canadian MOT teams.
6. Continue and/or expand the existing Alliance contracts with UMTRI and Lehman Injury Research Center.
7. Utilize Fatality Analysis Reporting System (FARS), supplemented with crash severity data as derived from Event Data Recorder (EDR) readouts.

Of course, an eighth option would be the establishment of all new crash investigation capability at a new site. This option was not explored, because it was judged to be substantially less efficient in terms of cost and time to get up and running, than the use of an existent capability. NHTSA has 24 NASS-CDS teams, 9 CIREN centers (two funded by the auto industry), and three SCI teams in place, with trained crash investigators. The Alliance has contracted for crash investigation with both UMTRI and Lehman in the past. It would be a shame not to utilize this existent expertise. It will be very time and capital intensive to try and build new independent capability. By using independent teams you also run the risk of criticism that the Alliance has hand picked the locations and protocols thereby biasing the outcome. The pros and cons of each of these options will be discussed in the ensuing sections.

II. Option 1 - Wring More Relevant Cases Out of NASS

The NASS is a nationwide crash data collection program sponsored by the U.S. Department of Transportation. It is operated by the National Center for Statistics and Analysis of the National Highway Traffic Safety Administration. NASS data collection began in 1979, but the NASS system was substantially re-evaluated in the mid-1980s. In its current incarnation the NASS has two major operating components: (1) the General Estimates System (GES) which collects data on a sample of police traffic crash reports; and (2) the Crashworthiness Data System which collects additional detailed information on a sample of police reported traffic crashes. The CDS includes 24 Primary Sampling Unit (PSU) research teams located in 17 states with two quality control zone centers. The GES includes an additional 36 PSUís located in 9 additional states.

Each PSU collects certain information from police accident reports (PAR), which are used to generate estimates of the nationís highway crash experience. Police reports, which include towed passenger vehicles and have a high potential for major injury will generally be selected for full investigation. The crashes investigated in NASS CDS are a probability sample of all crashes in the U.S. This type of sample design makes it possible to compute estimates that are representative of the entire country. The investigation of each case includes interviewing drivers and occupants, inspecting scenes and vehicles, reviewing official medical reports, and reconstructing crash dynamics.

The responsibility for operating the crash research teams, maintaining the quality of the field research data, and providing technical guidance for each PSU lies primarily with the two Zone Centers. The current Zone Center contractors are: Eastern U.S.-Veridian Engineering in Buffalo, New York and Western U.S.-KLD Associates in San Antonio, Texas.

NCSA made a run of the NASS sampled police reported crashes for the past year which involved a late model year vehicle (1998 model year or newer) and were involved in a crash with a severity of 25 mph delta V or greater. 470 crashes met this criteria and NASS-CDS investigated 370 of the 470. This leaves approximately 100 additional cases per year that could be sampled. Assuming that roughly half of these would have a frontal direction of force, approximately 50 would be desirable for evaluation of air bag system performance. Of course the 25 mph delta V criterion could be relaxed yielding more cases and the number of vehicles with post depowering air bag systems will continue to increase as time goes by. For the moment though, it looks like something on the order of 50 additional NASS-CDS cases could be investigated.

If it is desired to investigate these additional cases, this could easily be accomplished by contracting directly with the two NASS zone centers. All 24 PSUís are under the direction of the two zone centers and NHTSA has just two contracts with the zone centers to operate the entire NASS system. I have spoken with senior management and NASS contract management staff at NHTSA and the principal contract managers at the two zone centers and they do not see any major problems with the Alliance contracting for the collection of these additional cases. The way it is accomplished logistically is to use the existing NASS investigators on an overtime basis, i.e. evenings and weekends. In this manner, there is no disruption of the routine NASS-CDS investigations. This has been done in the past. For example, the National Highway Research Cooperative Project of TRB contracted last year for the NASS teams to investigate run off road crashes. NASS teams investigated these crashes on weekends, so as not to interfere with their normal NASS data collection activities.

A typical NASS-CDS case cost is approximately $1800, so the investigation of 50 cases per year would cost approximately $100,000, assuming that it is accomplished on an overtime basis. There would be no start up costs, such as training of investigators, since the existing NASS system and investigators would be utilized.

Of all options considered this is the most efficient in terms of both cost and time. It has the additional advantage of using a known and accepted investigation protocol with data quality control checks at the zone center. The NASS database itself is the most powerful in terms of analytical potential since it can be weighted up to represent all crashes in the U.S. The NASS database is publicly available; so all parties are free to conduct their own analyses of the data once it is reported.

III. Option 2 ñ Expand NASS so that it is capable of investigating more relevant cases

We saw in the discussion of Option 1, that the NASS-CDS system is ìwrung outî in terms of investigating crashes of relevance to the study of air bag occupant protection in high severity crashes. Thus, the only way to get more relevant crashes using the existing NASS crash investigation scheme is to add more capability to the current system. In discussions with both NHTSA and NASS Zone Center personnel, the most efficient and expedient way to get additional capability is to upgrade existing GES PSUs by staffing them with trained crash investigators. The NASS-GES operates in 36 PSUs that are not currently included in the CDS sample. Since all PARs are already being gathered at the GES sites, we know the universe of crashes and can do the sampling of relevant cases in the same manner as at existing CDS PSUs. The 36 GES sites are comprised of two different types: adjacent and remote. The adjacent sites are affiliated with existing CDS sites and can thus avail themselves of some of the expertise, support personnel, and other resources available at the CDS site. The remote sites do not have much more than part time employees gathering PARs. So from a logistical point of view the best way to expand is into the adjacent GES sites. However, if we use only the adjacent sites our ability to develop weighting factors may be compromised.

Another consideration is that some of the GES sites will be more suited to the sampling of relevant cases since they will have a greater number of late model and/or higher severity crashes. However, once again, if we choose the sites based solely on relevant case richness, we may compromise our ability to use weighting factors to make national projections. Thus, two issues must be decided which will affect how the sampling plan is developed: 1) the types of crashes to be investigated, and 2) the method by which the sample of crashes is obtained.

The types of crashes to be investigated can be defined in terms of the severity of the police reported outcome. Two possibilities are: 1) serious only, and 2) crashes of all severity. Once the type of crash has been defined, there are two possibilities for sampling crashes: 1) non-probability based (convenience sampling), and 2) probability based (random). The resulting matrix of potential combinations of the sampling procedures and crash types are shown in table1:

Table 1: Possible Sampling Plans

Crash Type	Sampling Procedure	
	Convenience	Random
Serious Only	Plan A	Plan B
All Crashes	Plan C	Plan D

Selecting cases by convenience sampling results in more individual cases relevant to assessing air bag performance in more serious crashes, but the information cannot be used to draw conclusions nationally. To do this, the sample of crashes must be based on a statistical procedure with known probabilities of selection. Further, drawing the sample from randomly selected PSUs allows the cases to be combined with the cases already being drawn from the CDS PSUs, thereby increasing the total number of cases available for analysis. Thus, if we want to make national projections, the sample must be drawn using either Plan B or D. Sampling serious only crashes would increase the number of crashes where the air bag system would be expected to play a major role in occupant protection, but would exclude many of the ìsuccesses,î where the air bag prevented injury. Thus, air bag effectiveness calculated from this data set may be artificially low. So from a purely statistical point of view, Plan D is preferable.

To quantify the tradeoffs inherent to the different ways of expanding the NASS system, I requested NCSA to make data runs on the NASS system in order to estimate the number of potentially relevant cases that could be investigated under each of the sampling plans outlined in Table 1. It was assumed that an investigator would be able to investigate 75 cases per year, as is currently done in NASS-CDS. One investigator at a total cost of approximately $150K would staff each expanded PSU. This cost includes start-up costs (such as training of investigators) amortized over four years, on going operating expenses, and NASS Zone Center supervision and quality control. For illustration purposes, lets assume that we want to investigate approximately 300 additional serious crashes per year. This would require the addition of 13 crash investigators at GES sites. The number of cases available under the four sampling plans are shown in table 2:

Table 2 ñ Number of Late Model Year Vehicle Crashes at NASS-GES Sites
Assuming 75 Cases Per Year Per Investigator (Standard CDS Case Content)

		13 ì Richestî PSUs	13 Randomly Selected PSUs
Serious Only Fatal or Hospitalized	Total Sample	975	510
	ΔV725 mph	130	70
All Severity Levels	Total Sample	975	895
	Fatal or Hospital	490	320
	ì Aî Injury	245	220
	Other Injury	240	355
	ΔV725 mph	75	60

Another possibility that was explored was to supplement the NASS-CDS data elements with SCI type reports. In addition to the expanded data elements, each report would be published as soon as it was finished. This would allow study of the individual cases on a continuous basis rather than waiting for the complete NASS file to be published on a yearly basis. It was judged that the typical crash investigator yearly caseload would drop from 75 to 50. Under this scenario the available number of cases for each of the four sampling plans is shown in Table 3:

Table 3 ñ Number of Late Model Vehicle Crashes at NASS-GES Sites
Assuming 50 Cases Per Year Per Investigator (SCI level detail)

		13 ìRichestî PSUs	13 Randomly Selected PSUs
Serious Only Fatal or Hospitalized	Total Sample	650	390
	ΔV725 mph	85	50
All Severity Levels	Total Sample	650	620
	Fatal or Hospital	325	245
	ìAî Injury	165	150
	Other Injury	160	225
	ΔV725 mph	50	40

The tradeoffs in the number of crashes are rather dramatic, but so are the tradeoffs in terms of the utility of the data collected. The primary advantage of using the NASS system is the ability to make national projections. Thus, there is not much advantage to using the NASS system if we do not preserve the probabilistic sampling as derived from the randomly selected additional PSUs. This limits the choice to Sample Plan B or D. You get more serious cases using Sample Plan B, but you give up many of the success stories where the air bag prevented injury. Plan D is essentially the same sampling scheme as currently used in NASS-CDS with the further restriction of only late model vehicles.

IV. Option 3 ñ Utilize NHTSA Special Crash Investigation Teams (SCI)

NHTSA currently has three SCI teams under contract. They are geographically located so as to represent capability to investigate crashes in the eastern, central and western U.S. Veridian Engineering in Buffalo, New York, the same contractor that manages NASS Zone Center 1, manages the east team. The central team is located at Indiana University in Bloomington, Indiana. Dynamic Science Incorporated in Anaheim, California manages the western team. These teams collectively and individually represent some of the most experienced and sophisticated crash investigation expertise that is available. The SCI teams are collectively investigating approximately 200 cases per year.

The teams are highly mobile and thus capable of investigating crashes anywhere in the U.S. NHTSA over time has established an ad hoc notification system that is capable of alerting the agency to crashes of particular interest in a timely manner. This facilitates investigation while vehicles; occupants and the scene are still accessible and the physical evidence is fresh. The cases of course are not selected using any probabilistic sampling technique and it is thus not possible to draw any conclusions about the representativeness of any sample that is drawn. The cost per case is relatively high. ìOn siteî cases, where pictures and data are gathered for the vehicle and scene as well as interviews conducted with occupants, cost an average of $8000. ìRemoteî cases, which generally do not have pictures or measurements of the vehicle, cost an average of $3000 per case. The average SCI investigation thus costs approximately $5000.

Discussions with each of the contractors as well as NHTSA personnel did not reveal any insurmountable obstacles to Alliance contracting directly with each SCI team for the gathering of additional relevant crashes. Two of the three SCI teams (Dynamic Sciences and Veridian) currently have contracts for crash investigation with parties other than NHTSA and thus were optimistic about taking on additional work and managing any potential conflicts. Indiana University does not currently investigate crashes for anyone other than NHTSA and they were a little apprehensive about NHTSA seeing a potential for conflict. I assured them that I had explored that with the agency and that the agency was ok with me talking to the team about the possibilities.

In FY-99 the NHTSA SCI teams investigated approximately 300 crashes, 200 of which were related to advanced air bag systems. In FY-2000 the NHTSA SCI budget has been reduced and the teams are slated to investigate 200 crashes, 100 of which will be related to advanced air bag evaluation. UMTRI has contributed approximately 150 of their cases (Alliance funded) to the NHTSA SCI file and expects to add another 50 shortly. . Lehman Injury Research Center (Alliance funded) recently sent approximately 30 cases (involving depowered air bags only) to NHTSA. The combined NHTSA SCI file currently contains over 400 cases related to advanced air bags and that total is expected to climb to approximately 600 by the end of the year.

V. Option 4 ñ Utilize Existing CIREN Centers

The Crash Injury Research and Engineering Network (CIREN) is a multi-center research program involving a collaboration of clinicians and engineers in academia, industry, and government pursuing in-depth studies of crashes, injuries, and treatments to improve processes and outcomes. CIREN is acquiring a wealth of more detailed injury data in conjunction with crash investigations using nine Level 1 trauma centers located at the University of Medicine and Dentistry of New Jersey in Newark, the Children's National Medical Center in Washington, DC, the William Lehman Injury Research Center in Miami, Florida, the National Study Center for Trauma and EMS/ R Adams Cowley Shock Trauma Center in Baltimore, Maryland, Harborview Injury Prevention & Research Center in Seattle, Washington, the San Diego County Trauma System in San Diego, California, the University of Michigan Medical Center in Ann Arbor, Michigan, the University of Alabama at Birmingham, Alabama (funded by Mercedes), and the Inova Fairfax Hospital Trauma Center in Falls Church, Virginia (funded by Ford).

To date, the CIREN centers have investigated nearly 1000 crashes. Approximately 900 of these crashes are now online with the computer network that links the centers. However, only 300-400 of these cases currently has complete data on all aspects of the crash. The annual funding for each center is in the $450-$500K range and each center is collecting approximately 50 cases. The average case cost is thus in the range of $9,000-$10,000. The FY 2000 contract renewals will be closer to $400K, dropping the average case cost to approximately $8,000.

The cases are not selected according to any kind of probabilistic sampling scheme and are the tip of the iceberg in terms of severity since only the most severely injured occupants are transported to a Level 1 trauma center for medical treatment. The cost per case is the highest of any investigated alternative. On the plus side, the medical information is the most detailed and comprehensive, since the team is essentially housed within the attendant medical treatment facility.

VI. Option 5 ñ Utilize Existing Canadian MOT Teams

The Ministry of Transport in Canada is currently contracting with eight University based teams to investigate crashes. There is a three-point focus to the current work: second generation air bags, side impact (crashes mirroring FMVSS 214 test), and vehicle defects.

The second-generation air bag crash investigations focus on all crashes involving vehicles of the last two model years (1999 and 2000) where the air bag deployed, regardless of crash severity or expected injury outcome. Alan German, who directs the studies for MOT, estimates that the average crash investigation costs approximately $2,700 (US). He believes that the network could be expanded (there were 10 teams at one time) or the caseload at each site could be expanded. The cost per case is quite attractive, reflecting the current lower cost of doing research in Canada.

I see two drawbacks to contracting with the Canadian teams. The case sampling is a convenience sample similar to the special crash investigations in the U.S. We thus would not know what the cases represent in terms of the whole spectrum of crashes. Secondly, the crash involved occupants are restrained more than 90% of the time. The sample would thus be composed almost exclusively of restrained occupants, which is not the focus that the Alliance or the NHTSA are looking for.

VII. Option 6ñ Continue and/or Expand Efforts with Current Alliance Contractors

Alliance currently contracts with the University of Michigan Transportation Research Institute (UMTRI) and the William Lehman Injury Research Center at the University of Miami to investigate crashes involving second-generation air bag systems.

I discussed the current workload and possibility for expansion at UMTRI with Dr. Larry Schneider and Joel MacWilliams. UMTRI is currently investigating 100-150 cases per year with 95% of the cases coming from Washtenaw and the other counties surrounding the Ann Arbor, Michigan area. They are currently investigating all crashes of late model year (1998 and newer) vehicles involved in a tow-away crash where one or more occupants were transported to the hospital. Many of these crashes turn out to be at fairly low delta Vs; in the 10-20 mph range. Joel believes that they could nearly double the number of cases by hiring one or two additional investigators and expanding into other Michigan and Ohio counties. This would be contingent on gaining the cooperation of the appropriate medical and law enforcement entities in order to gain access to the medical records of crash victims and set up a crash notification system. Start up time would probably be at least 6 months, based on the need to hire and train additional investigators and secure the necessary cooperation of medical and law enforcement officials.

In discussions with Dr. Augenstein, who is the head of the research project at Lehman, I learned that he is interested in setting up what he called a ìClearing Houseî for CIREN cases. The concept, as I understand it, would be to have a panel of experts that would review the crash reconstructions and injury mechanisms to ensure the technical integrity and uniformity of the conclusions. Dr. Augenstein has submitted an informal proposal to Alliance for such an activity.

VIII. Option 7 ñ FARS Cases Augmented with EDR Readouts of Crash Severity

This option was the brainchild of Jim Simons, who is the Director of the Office of Regulatory Analysis and Evaluation at NHTSA. Jim is heading up an internal NHTSA task force that is looking into the research, data and analysis that will be necessary for answering the remaining questions about the performance of advanced air bag systems.

The concept here is to meld the Fatality Analysis Reporting System (FARS) data, which is a census of every motor vehicle crash that results in fatality to a vehicle occupant or nonmotorist, with a readout of the EDR to provide information about the severity of the crash. FARS contains good information on the injuries incurred by the occupants and the general configuration of the crash; however, there is generally not good information on the severity level of the crash. Many of the post 1998 vehicles of interest contain EDRs that are capable of recording the change of velocity during the crash and other items of interest such as air bag deployment time and level of deployment for multi-level systems. If it proved feasible to obtain timely notification of FARS crashes and train investigators to locate the vehicles and readout the EDR, a very powerful database could be synthesized; albeit only for those vehicles that contain a readable EDR.

NHTSA is still investigating the feasibility of initiating such a concept. If NHTSA goes ahead, the industry should consider at that time what support, if any, it might want to contribute. At the very least, the effort should be supported with technical expertise and hardware to readout the EDRs, as discussed elsewhere in this paper.

The FARS database as presently constituted is very powerful for evaluating air bag effectiveness in fatal level crashes. NHTSA has on going plans to update analyses of air bag effectiveness using FARS. The marriage of FARS with HHSís Multiple-Cause-of ñ Death file makes an even more powerful data set, since it contains much more extensive injury data.

IX. Discussion and Conclusions

A. What questions are we trying to answer?

There are numerous questions that need an answer before industry and government can make final decisions about the future direction of air bag system design. From a global perspective, probably the single most important question that needs an answer is: What level of air bag energy absorption capability gives the optimum level of benefit in terms of occupant injury reduction? The answers to this question will likely drive decisions about the appropriate severity level to test air bag systems for high-speed protection. To answer this question with a degree of precision that will satisfy all involved parties will require crash data that represents the whole spectrum of crash severity and crash configuration where air bags could reasonably be expected to offer occupant protection. It is well known that air bag system design involves numerous tradeoffs. If the aggressivity[1] of the air bag system is increased, it is likely that high-speed protection will be enhanced (at least for some occupants), but probably at the expense of more inflation induced injury in crashes of lower severity. This is but one of the many design tradeoffs facing the restraint design engineer. Likewise, there are a myriad of circumstances that are occurring in real world crashes that lead to the determination of the overall effectiveness of the system across all crashes for all sizes and types of occupants. It is these precise tradeoffs that are largely unknown at this time.

To effectively answer this question we will need to know not only what the individual tradeoffs are, but also how often they occur in the real world crash environment. Anecdotal crash data (crashes investigated from a convenience sample), such as SCI and CIREN crashes, can help answer the first part, but do not help very much with the second part. Thus, I believe that our principle source of crash data will need to be a data set that is drawn with a least a rudimentary form of probabilistic sampling. In this manner we can then ascertain how often the individual tradeoffs are occurring in the total crash environment. The only way I know of to accomplish this at reasonable cost and in a timely manner is to supplement the current NASS-CDS system. Of course the FARS data will also be invaluable in assessing the overall system effectiveness in fatality producing crashes.

We will undoubtedly also want to answer a whole series of questions that relate to whether the second generation air bags have addressed the problem of air bag induced injury. These questions will be addressed in a global or fleet wide sense by the NASS-CDS and FARS data. However, it seems inevitable that individual manufacturers will introduce air bag systems that address bag induced injury using different design approaches and hardware. It would be many years before we could address the performance of individual make/model systems using NASS and FARS. This is where the anecdotal databases such as SCI and CIREN can prove invaluable. A good clinical evaluation of newer systems using suppression technologies, variable inflation levels, more sophisticated crash severity sensors, deployment algorithms, etc. can be accomplished utilizing the special crash investigation capabilities that are already in place. If there are problems with the latest technological solutions we need to know right away.

[1] Aggressivity in this context is meant to include all air bag design variables that can influence the likelihood of air bag induced injury. Some of the more important variables are: maximum inflation pressure, rate of inflation, bag size and shape, deployment direction, deployment door design, multiple deployment levels, suppression of deployment and time of deployment.

B. How many crashes will have to be investigated to give us reliable answers?

NASS-CDS is currently investigating 300+ cases per year where a late model car or truck is involved in a severe crash with a frontal direction of force. With the addition of 13 crash investigators at randomly selected GES sites, as shown previously in the NASS expansion illustrative example, the number of cases could be doubled to approximately 600+ crashes. The question then arises: ìWhat does this buy us in terms of being able to discriminate differences in effectiveness between the pre and post depowered air bag systems?î I asked Dr. Charles Kahane, a leading NHTSA statistician who has 25 plus years experience in analyzing air bag effectiveness, to address this question. The following was his response:

We donít know the difference in effectiveness from MY 1998-2000 depowered air bags and the advanced air bags. Thus, a sensitivity analysis had to be performed saying, ìIf the difference in effectiveness were X, how much data would you need to statistically prove that?î

We started by looking at FARS, assuming you had two cohorts of data for cars and light trucks, looking at frontal crashes defined as 11,12, or 1 oíclock. The baseline would be MY 1998-2000 vehicles and the question is: How many years of FARS data would you need assuming the whole fleet at once changed over to ìadvancedî air bags.

Table 4 presents the results of two assumptions. First, it looks at belted and unbelted occupants. But the much more realistic equation looks at just the unbelted occupants. We think the only noticeable difference will be for the unbelted occupants. This table is read, for example, If the baseline MY 1998-2000 vehicles are assumed to have an overall effectiveness of air bags for belted and unbelted occupants of passenger cars and light trucks of 11 percent then if the overall benefit of air bags dropped to 5%, you would know with one year of FARS data. So, if there is a real disaster, we will know relatively quickly. The smaller the difference, the more data you need.

Table 4 - FARS Data
(Assuming a Whole Fleet Changeover to Advanced Air Bags
Beginning Oct. 1 Before Year 1)

	If Effectiveness Dropped to	You Would Know With the Following Years of FARS Data
Belted and Unbelted Baseline 11% Effective	5%	1 year
	7%	2 years
	8%	3 years
	9%	4 years
Unbelted Only Baseline 13% Effective	3%	1 year
	7%	2 years
	8%	3 years
	9%	4 years

The NASS case is conceptually more difficult. Assuming a full fleet of advanced air bags starting Oct, 1, prior to year 1, and 4 years of regular NASS CDS data, 2 cohorts of cars and light trucks, last 3 model years of pre-advanced systems (depowered) and first 4 model years of advanced systems

Frontal crashes with Delta V known and ≥ 25 mph **BELTED AND UNBELTED COMBINED**

We could expect about 140 people with maximum AIS ≥ 3 in the depowered cohort and 85 in the advanced cohort (unweighted cases), assuming advanced and depowered are equally effective (there are fewer cases in the advanced cohort because many of these vehicles are not on the road the full 4 years).

For statistical significance at the one-sided .05 level (the lowest defensible level of significance):

To read this table: We couldnít really do the same effectiveness levels as for fatals, but this table says (looking at the second line) that if advanced air bags increased the risk of AIS 3+ by 20 percent (we observed 116 cases when we expected 97 cases), you could prove with the data you currently are collecting in NASS for 4 years plus an additional 51 cases (160 + 116 = 276 -current anticipated collection of 140 + 85 = 225). If the difference is a 10 percent increase in risk, you would need 901 more cases over the 4 years than would currently be collected by NASS to statistically prove advanced air bags had a 10 percent higher risk than depowered air bags. And youíd need those cases in the right proportion.

Table 5 - NASS-CDS Data
Belted and Unbelted Combined

Advanced Risk Increase (%)	Depowered Observed	Advanced Expected	Advanced Observed	Additional Cases Needed
10	675	410	451	901
20	160	97	116	51

This is working with unweighted data. With weighted data, it would undoubtedly be worse (i.e., an even larger reduction would be needed to demonstrate statistical significance). This also deals with all types of occupants and all types of injuries. Obviously, larger reductions would be needed for significance on specific groups of occupants and specific types of injuries. This is also working with beta = .5. To reduce beta to .1 (i.e., to assure yourself of getting significant results even with an unlucky sample), you would have to double these numbers.

Now let us assume that advanced and depowered air bags have the same effectiveness for belted occupants, and all the change is in the **UNBELTED occupants**. Unbelted, we could expect about 75 people with maximum AIS ≥ 3 in the depowered cohort and 31 in the advanced cohort, assuming advanced and depowered are equally effective. For statistical significance at the one-sided .05 level (the lowest defensible level of significance):

Table 6ñ NASS-CDS Data
Unbelted Only

Advanced Risk Increase (%)	Depowered Observed	Advanced Expected	Advanced Observed	Additional Cases Needed All Unbelted
10	866	358	394	1,151
20	203	84	101	198
30	87	36	47	28

To look at just the unbelted, to prove there is a 20 percent increase in risk, you would need 198 more unbelted cases (304 cases compared to 106 we currently would collect).

To prove there is a 10 percent increase in risk, you would need 1,151 more unbelted cases (1,260 cases compared to 106 we currently would collect).

Dr. Kahaneís analysis tells us that if we double the number of NASS-CDS cases, that we will be in pretty good shape as far as discriminating any catastrophic drop in air bag system effectiveness. The additional 300 or so cases per year would allow the detection of a 20% drop in effectiveness within approximately two years. However, the above analysis assumes that the whole fleet changes over simultaneously to advanced air bags. The reality is of course that we will see many different forms and types of advanced air bag systems introduced over time. Obviously, if only half the fleet changes over it will take twice as long to collect the needed data. And you have to consider whether it will be meaningful to collect data on specific make/models, e.g., those that have dual level inflators. Since we donít know what the advanced air bag risk is, obviously the more cases the better the analysis and the more refined we can get.

X. Related Issues

How do you contract with the NASS, SCI and/or CIREN teams and avoid the appearance of ìaugmentationî?

As a general proposition a Federal agency may not augment its appropriations from outside sources without specific statutory authority. When Congress makes an appropriation, it is also establishing an authorized program level. In other words, it is telling the agency that it cannot operate beyond the level that it can finance with its appropriation. To permit an agency to operate beyond this level with funds derived from some other source without specific congressional sanction would amount to a usurpation of the congressional prerogative. Restated, the objective of the rule against augmentation of appropriations is to prevent a government agency from undercutting the congressional power of the purse by circuitously exceeding the amount Congress has appropriated for that activity.

When I first started the paper my initial thought was for Alliance to contract independently with the NASS, SCI or CIREN contractors (if it turns out this is what is desired) and avoid having the money come through NHTSA. From a lay mans perspective this just seemed cleaner. I later discussed the issue of augmentation with John Donaldson, Esq. in the General Law Division of the Office of Chief Counsel at NHTSA. Mr. Donaldson has been the agency expert on legal issues related to budget and congressional appropriations for a long time and he is very knowledgeable in these matters. He said that at one time Congress was very concerned about augmentation of Federal budgets, particularly for regulatory agencies, when the money comes from the regulated party. However, he said that in more recent times Congress has become very enamored with the concept of ìpartneringî through the use of such tools as cooperative agreements or gift authority (DOT has statutory gift authority). Thus, he believes that we can do it fairly safely either way i.e., by contracting directly or through a cooperative agreement between Alliance, NHTSA and the contractor. At some point we may even want to check it out with the staffers on the congressional appropriations committees. For the moment, I do not see augmentation as a showstopper. It is something that we will have to remain cognizant of and deal with in an appropriate manner when the time comes.

How can we get accurate determination of crash speed?

Crash speed will be one of the most crucial (and at the same time controversial) variables to determining air bag performance. It is also one of the most difficult to accurately determine after the crash. Many of the vehicles with second-generation air bags have onboard crash recorders (EDRís). Every effort must be made to ensure that the crash investigators are trained and have the best tools available for downloading data from the EDR. I know that GM has made available to crash investigators portable PCís and software for downloading the EDR, Ford likewise has made available hardware to access the 2000 Taurus EDR. Other manufacturers should be encouraged to provide similar tools. Accurate determination of the higher crash speeds, air bag deployment times and levels will be imperative, if we are to convince detractors of the high-speed protection of second-generation air bags.

In discussions with the various crash investigation teams there was widespread differences in their knowledge of EDRs and widespread differences in their success in being able to readout the EDR. There needs to be a much more concentrated effort on both the part of government and industry to bring up the level of expertise and equipment for readout and utilization of EDR data.

XI. Conclusions/Recommendations

1. By the end of the year there should be nearly 1000 ìSCI Typeî convenience sampled cases available through a combination of NHTSA SCI, CIREN and Alliance contractors. The 1999 FARS file is available and preliminary analyses of air bag effectiveness in fatal crashes have already been completed. Analyses based on the FARS and SCI files will be very helpful in getting early warning of things gone wrong. They will also tell us a lot about the field experience with new technology and whether it is performing as designed. They will also give us an idea as to whether the air bag induced injury problem has been moderated.

   But while analyses based on these files can tell you ìHow Much,î they canít tell you ìWhy.î Occupant protection from inflatable devices is unlike occupant protection from any other means, because it is the only occupant protection system that puts energy into the crash. It is this addition of energy to the crash that has the potential to cause injury at the same time that it has the potential to prevent injury. It is the magnitude of these tradeoffs that is unknown. To get the answer to the ìWhyî question we will need a probability based data collection system, wherein results of data analyses represent the entire spectrum of crashes and can be projected to the national level. Right now the only data system with that capability is NASS. The NASS system has many warts, but it is the only game in town for the moment. So I recommend that we contract with the two NASS Zone Centers to wring out all additional cases of late model (1998 and newer) vehicles involved in high severity level frontal collisions. This should result in approximately 50 additional NASS-CDS cases per year at a cost of approximately $100k.

2. To further expand the collection of NASS cases, I recommend that we contract with the NASS Zone Centers to put trained crash investigators into GES sites. The additional PSUs should be selected on a random basis so as to preserve the probabilistic sampling scheme of NASS. The cost will depend on the number of additional crash investigators at a cost of approximately $150k per site.

3. I do not see any need at this time to expand the collection of convenience-sampled cases. By years end, the SCI file will contain over 600 cases involving second-generation air bag systems. NHTSA is continuing to collect SCI cases involving second-generation air bags at the rate of 100 per year. This is supplemented by the 200 cases per year that are currently being collected by UMTRI and Lehman under contract to Alliance (second generation air bag cases are emphasized in both contracts). The CIREN centers are collecting approximately 450 cases per year, a significant portion of which should be appropriate for evaluation of second-generation air bag system performance. Thus, over the next few years, in excess of 1000 cases will be available to make anecdotal judgments about the

performance of second-generation air bag systems on a case-by-case basis. However, there is only so far one can go with anecdotal data. These cases will never permit the analyst to quantify the tradeoffs for different sizes and gender occupants, restrained vs. unrestrained, crash severity, etc., in order to make a fleet-wide assessment of the appropriate level of air bag aggressivity for optimal occupant protection.

4. I see technical merit in Dr. Augensteinís proposal to set up a Clearing House for CIREN and SCI cases; however, this definitely falls into the category of Gilding the Lily. CIREN cases already cost upwards of $10k, supposedly because we are purchasing top level medical and crash reconstruction expertise. In any event, NHTSA recognizes the lack of uniformity in reporting CIREN case data and has plans to put in place a data quality control process analogous to that now used for NASS. I recommend postponing any decision on this issue until NHTSA announces its future plans regarding data quality control for the CIREN program.

5. Aggressively support the readout of EDRs by crash investigation teams. A much more concerted effort needs to be made to train crash investigators and get them the tools they need to readout the EDR. Delta Vs as calculated by CRASH and other currently available computer aided crash reconstruction tools have been repeatedly called into question. Reliable estimates of crash severity, that all parties can agree upon, will be crucial to facilitating the analysis of the appropriate level of high speed protection that air bags are capable of providing without compromising occupant protection at other severity levels. Further, other EDR data, such as air bag deployment time, will be crucial to understanding the potential for air bag induced injury. This information will become even more crucial in the future as we move to more sophisticated air bag systems employing multiple levels of deployment, suppression and more sophisticated crash sensors and deployment algorithms. For example, without the EDR readout for vehicles equipped with multi-level air bags, the crash investigator may not be able to ascertain whether one or both levels of the air bag deployed (since it now appears likely that the second level inflator will be burned for environmental reasons even in instances where only the first level is fired for occupant protection).

6. Closely monitor NHTSAís plans for analysis of FARS data. NHTSA routinely updates its analysis of air bag effectiveness in fatal crashes yearly using the latest FARS file. The FARS analysis will give an early indication of whether overall effectiveness has been degraded with second-generation air bags for fatal level crashes. We should seriously consider conducting our own FARS analyses, now that the 1999 FARS file is available. If NHTSA decides to pursue the project which supplements the current FARS data with EDR readout data, then the Alliance will need to decide whether they would like to participate in some way in this endeavor. Any FARS analyses should consider use of a married file with the Multiple-Cause-of-Death database.

7. Augmentation is an issue that will need to be addressed if we decide to contract with any of the entities that now administer the NASS, SCI or CIREN teams. Legal staff on both sides will need to discuss whether it makes more sense for Alliance to negotiate contracts directly with the contractors, sign a cooperative agreement among the three parties, or pursue some other path acceptable to both parties.

During the development of this paper I have had discussions with key personnel at NHTSA, NHTSAís crash investigation contractors, NTSB, Canadian MOT, insurance industry (in the form of State Farm and IIHS), and Alliance crash investigation contractors (see Appendix B for a complete list of contacts). Collectively, this group represents many years of expertise in the art of collecting and analyzing crash data. I described in very general terms my thinking on the best approach for gathering crash data for evaluation of second-generation air bag systems (I represented the conversation as my own thoughts and not necessarily that of the Alliance). I did not receive any negative feedback on my proposed approach or any suggestions for a ìbetter wayî of going about the task at hand. That is not to say that it is a perfect approach, only that a lot of people with extensive experience and background couldnít come up with a better way.

Appendix A

Alliance Research Project

Unbelted Occupant Evaluation in High Severity Crash Events
Field Data Collection and Analysis

Objective: To obtain additional real-world test data of unbelted occupant injury performance in high severity crash events. Collection and analysis of additional high speed unbelted occupant data will assist the government, industry, safety community, and other relevant organizations in determining the appropriate next phase of high-speed unbelted occupant crash test requirements (post-TEA 21).

Project Completion: September 1, 2003 (3 years)

Organize a Blue Ribbon Expert/Project Management Panel

- Representatives from government, industry, safety groups, and other relevant organizations.
- Panel oversees the management of data gathering processes and barrier crash test program.
- Panel assesses field performance data and barrier crash data and recommends appropriate unbelted crash test requirements (e.g., higher speeds, unbelted offset).

High Crash Severity Real-World Data Collection and Analysis

1. Alliance supports the evaluation and analysis of existing depowered field data including NHTSAís current collection of depowered air bag cases (existing data).

2. Collect and analyze additional real-world high-speed crash data for vehicles equipped with both depowered air bags and pre-depowered (before 1998) air bags (new data).
   - Alliance contracts independent organizations (e.g., UMTRI, TSC, IIHS) to manage the project and collect the field data and perform the crash reconstruction.
   - Alliance arranges a crash notification process with Insurance Industry.
   - Data collection focuses on high-speed crash cases with unbelted front occupants.
   - Correlate real-world data to baseline barrier crash test data.
   - Detailed vehicle structural evaluation and CAE occupant modeling used.
   - Coordinate with CIREN centers.

Appendix B

List of Contacts During Development of Paper

NHTSA

Robert Shelton, Executive Director
Ray Owings, PhD., Associate Administrator for Research and Development
Joseph Carra, PhD., Director of National Center for Statistics and Analysis
Lee Franklin, Chief of the Crash Investigation Division
Dennis Utter, Chief of Sample Design and Quality Control& State Data Branch
Gary Toth, Manager of NASS contracts
Chip Chidester, Manager of Special Crash Investigations
Keith Brewer, PhD., Director of the Office of Human-Centered Research
John Hinch, Staff Assistant
Lou Brown, Manager of CIREN teams
Bill Walsh, Associate Administrator for Plans and Policy
Jim Simons, Director of Office of Regulatory Analysis and Evaluation
Charles Kahane, PhD., Chief of the Evaluation Division
John Donaldson, Esq., Office of Chief Counsel

Canadian Ministry of Transport

Danius Dalmotas, Chief, Crashworthiness
Alan German, Chief, Collision Investigation

NTSB

Vernon Roberts, Office of Highway Safety
Elaine Weinstein, Acting Director of Office of Safety Recommendations and Accomplishments

NASS Zone Centers

Don Hendricks, Veridian Engineering, Zone Center 1
Steve Mavros, KLD Associates, Zone Center 2

Special Crash Investigation Teams

Ron Drahos, Indiana University
Jim Perry, Dynamic Sciences
Don Hendricks, Veridian Engineering

Insurance Industry

Charles Sollars, State Farm
Sam Boyden, State Farm
Sue Furgeson, PhD., IIHS

UMTRI

Lawrence Schneider, PhD., Head of Biosciences Division
Joel MacWilliams, Crash Investigation

William Lehman Injury Research Center

Jeffrey Augenstein, M.D., Professor of Surgery
Elana Perdeck
Jim Stratton, Crash Investigator