Title: **From Offboard to Indummy Crash Test Data Acquisition**

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The first automotive crash tests have been performed in the 1970s. Back then, data acquisition systems have been large and heavy and the only possibility to acquire data was to use long and cumbersome umbilical cables between the sensor in the dummy and the data acquisition system that was located e.g. in the control room. Over the years data acquisition systems have been improved quite dramatically in performance and size. This paper shows the history of crash test data acquisition from the early beginning to today's indummy solutions.

The early days

In the early days of crash testing - before 1970 - most of the dummies that have been used were models derived from military testing. These dummy models had basically no possibility to install transducers and therefore the need for a data acquisition system was basically not existing.

The Off-Board Systems

In the 70ties the first dummy with cavities for transducers was used. At the same time it was mandatory to acquire and store the recorded data from these sensors. At that time data acquisition systems were large and heavy and mostly analog. This means, the data from the transducers was stored on tape in an analog way. To review the data it was necessary to replay the tape and visualize the graph again on an oscillocope or on a strip chart recorder. Since the equipment was so large it was not possible to put any electronic components on-board a crash test vehicle. Therefore, it was necessary to transfer the signal from the transducers via long umbilical cables to the off-board equipment. Obvisously this method had significant problems. Since the signal from the transducers is in many cases so small the resistance of the cables had a significant impact on the signals. At that time it was necessary to "calibrate" each channel before the test. This calibration was done by putting a known resistor in parallel to one arm of the bridge. Sometimes this parallel resistor is also called a shunt. The shunt calibration was a long and cumbersome process and with today's digital systems this test step is no longer necessary. However, a lot of people crash test engineers still call the checking of the cabling and the amplifiers even today "Shunt Calibration".

The first on-board system

In 1976 the German "Bundesanstalt für Straßenwesen" (German Institut for Highway Safety) was building a new crash test facility in Cologne, Germany. The goal was to create the most advanced crash facility in Europe. Part of the program was the purchase of a data acquisition system that should travel on-board the car during the test. Since no company around the globe was able to

deliver such a ruggedized data acquisition for the use inside the crash vehicle the German BAST contacted the company Kayser-Threde in Munich, Germany. Kayser-Threde was known as company that designed and produced data acquisition systems for space and airborne applications. Since these system had to be very ruggedized it was clear to the BAST that Kayser-Threde is the perfect partner to build the first on-board crash test system. They placed an order with Kayser-Threde and one year later the new system - called K1222 - was delivered to the BAST.

This system was a so called PCM System. PCM stands for "Pulse Code Modulation". This method was used to transfer the data from several data channels at high speed via a cable or wireless connection over long distances. The analog voltages from the amplifiers (which have been placed on board) were simply spoken converted in pulses which represented the analog value. The conversion job was done by the so called Encoder. At the end of the umbilical cable a so called decoder converted the pulses back to analog values. From there it was possible to digitize the analog values or to store it directly on tape. This means, the first on-board systems got rid of one big problem that off-board systems had: It was not necessary anymore to transfer the small signal from transducers to the off-board system. All the amplification and signal conditioning was done on-board. In addition, the number of lines for the data transfer was reduced significantly. Before it was necessary to run 4 to 6 lines to every transducer. With the PCM technology this was reduced to a few lines.

The second generation of on-board systems

The next logical step for the on-board systems was to put the digitizing and the storage also in the on-board unit. In the mid of the 80ties the miniaturization has progressed so far that this became possible. Several companies such as Kayser-Threde, MTE, and Messring developed such systems at that time. All the functions of a data acquisition system were integrated in one box: Amplification, signal conditioning, A/D-conversion, and data storage. In order to communicate with the outside world these system had a command interface for remote control and a high speed interface for data transfer. To control these interfaces the boxes needed a certain "intelligence" or - with other words - a micro controller. This micro controller was able to control the whole system and - at the same time - to run a test completely without an external controller. At that time it was possible to run tests without any cables since the on-board systems were completely self contained as long as they were powered by an on-board battery.

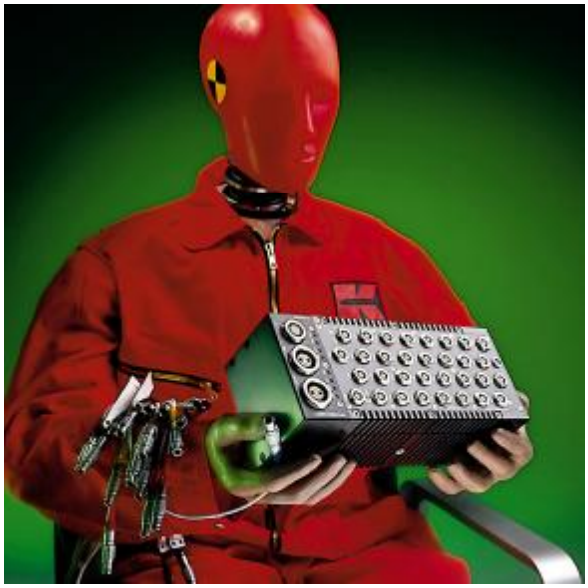
Vehicle equipped with 2 K3600 systems

Typically these systems had a mass of 20 kilograms for about 64 data channels. For a long time this was acceptable since the typical number of channels for a test never exceeded this amount of channels. However, in the beginning of the 90ties the number of channels per test was growing and growing and a lot of crash test engineers had the problem that they could not fit the data acquisition systems in the cars anymore. This

was the time for the third generation of on-board systems.

The third generation of on-board systems

In order to fulfill the requirements for hundreds of channels per test it was necessary to significantly reduce the size and mass of the on-board systems. In 1996 Kayser-Threde started in a joint cooperation with BMW, and Audi a project that was internally called "Miniaturized Data Acquisition Unit" or MINIDAU. The goal was to reduce the size and mass of the data acquisition system by a factor of 3. This means, that the mass of a 32 channel system must not exceed 3 kilograms including a battery for emergency situations. The most critical issue in the design was to keep the functional features of the second generation of on-board system and – if possible – to improve them.



MINIDAU System with 32 Channels

By using the newest technology available the design team at Kayser-Threde was able to fulfill the requirements. In some areas the features of the older K3600 system were even improved. With the MINIDAU it was possible to acquire data with higher sampling rates (20 kHz) and higher resolution (16 Bit) than ever before. After its market introduction in 1997 Kayser-Threde sold round about 16000 data channels of this system to car manufacturers and test houses around the world. This means, the MINIDAU became the best selling crash test system ever.

At the same time when Kayser-Threde introduced the MINIDAU as an on-board system the American company Robert A. Denton introduced also a very small data acquisition system. However, this system was designed to be mounted inside a dummy. The idea was to replace the original spine box of a Hybrid III dummy with a box that contains all the necessary electronic and the connectors. The IDDAS system (Intelligent Dummy Data Acquisition System) offered a total of 48 analog channels and was fully programmable. For automotive crash testing this system was too expensive and incompatible with other existing equipment. However, the IDDAS system was sold in several non-automotive applications such as aircraft ejection seat testing. Furthermore, the IDDAS system was the first system inside a dummy and therefore the starting point for the next generation of crash test data acquisition systems: The In-Dummy systems.

The In-Dummy systems

As mentioned before the IDDAS system was the first system that added the complete data acquisition channel chain to the dummy.

In the meantime there are several ideas and solutions available for In-Dummy data acquisition and it is not easy at the first sight to see the differences of the concepts. In order to find out about the differences we should devide the signal path into several stages:

- Signal Conditioning

- A/D-Conversion
- Data Memory
- Communication and Control

In order to achieve an ideal in-dummy system that fits into most of the dummies it is almost necessary to split the different function blocks to get a distributed system. Putting every function into one place might result in a hot spot inside the dummy since all the power is concentrated in one place. This might cause the dummy to heat up internally and this has to be avoided under any circumstances.

Now let's look at the several available approaches:

The WorldSID Approach

In the WorldSID the American company DTS proposed a distributed solution where the signal conditioning is separated from the A/D-conversion and the memory. The amplifier is placed close to the transducer and the amplified signal is then transferred to a multiplexer and an A/D converter. The data is then stored in the central unit.

The DiMOD Approach

The DiMOD concept was designed by Volkswagen, Endevco, and Hentschel. The idea is to put the signal conditioning and the A/D-conversion in a separate module and transfer the data on a digital serial bus to a central recorder with memory and communication control.

The MICRODAU Approach

Kayser-Threde is currently also working in a concept for an in-dummy data acquisition system. Kayser-Threde wants to place the complete data acquisition unit including signal conditioning, A/D-conversion, and memory very close to the transducers. During the test all the test data will be stored for each channel on this so called data acquisition frontend. After the test the data will be transferred via a USB serial interface to the in-dummy controller. The in-dummy controller is basically a ruggedized PC with network capabilities. Several dummies can be integrated in existing MINIDAU systems by using the on-board Dummy-Hub. The MICRODAU concept supports up to 256 channels in one dummy.

The attached diagram gives an overview on the different systems and where the functional components are located.

The Future

Today, all in-dummy approaches are more or less concepts and prototypes and not ready for use before 2003. All approaches have advantages and disadvantages and the future has to show which approach is the most feasible. However, there are two tendencies that recognizable:

- It will take several years until in-dummy solutions will replace the classical on-board systems. Most of the test laboratories have spend a tremendous amount of money to equip their facilities with large quantities of on-board systems and nobody really wants to change quickly to new technology.

- In the future the best place for the data acquisition systems will be the transducer itself. This is basically the final goal of all developments. The different in-dummy concepts today are just different approaches to this final solution and the next years will show which way to go.

No matter which direction the technology will go: Crash test data acquisition has a long history and a exciting future!