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# Why a DCC Makes Life Easier with Multi-Component Sensors for Forces and Moments

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**Summary:**
DCC (digital calibration certificate) is in the starting blocks. The PTB working groups and countless experts from industry are contributing to the standardization and machine readability of the DCC and are in the final sprint [1]. The advantages of the DCC result from the automated management of thousands of sensor calibrations, and the associated economic savings are estimated at several billion euros per year in Germany only. This article shows another important aspect: the user-friendly simplification of complex calibration data.

**Keywords:** DCC, Multi-Component, Calibration, Certificate, Uncertainty Vector

## Introduction

When the advantages of the DCC are discussed among experts, the focus is on simplifying the handling of large quantities of calibration certificates. For example, in a chemical factory where thousands of process monitoring sensors are installed and need to be traced back, an uninterrupted digital chain without media changes from the calibration laboratory to the application can save enormous amounts of time and greatly reduce the potential for errors.

However, the DCC is not only of interest in the cases mentioned above, but also in cases where complex data occur which are related to each other in some way. Or where large volumes of data are generated. A sensor that can metrologically competent reduce such complex data and present its performance to the user as simply as possible is called a smart sensor. The DCC can transport all the information required for a smart sensor. If the DCC is also cryptographically signed and stored on the sensor, a complex structure becomes a plug-and-play device.

## Multi-component sensors are complex

Multi-component sensors are widely used in industrial applications like testing of components or structures, in robotics or crash testing in the automotive industry. These sensors provide information on externally applied forces and moments, usually oriented in a cartesian coordinate system. In most cases, monolithic base bodies made of steel or aluminium with strain gauge applications are used. These monolithic bodies exhibit a more or less good decoupling of the externally introduced force and moment vectors. The residue of the decoupling is often called crosstalk. This means a sensor that measures three forces and three moments requires at least 6 x 6 elements for its characterization. As the behavior can also have non-linear components, this can result in a multiple of the 6 x 6 matrix. It's easy to lose overview, apart from the fact that it's also not easy to check the accuracy or measurement uncertainty of the sensor. And it's even easier to lose focus when the expertise lies in the task of testing components or structures, in robotics or crash testing - and not in metrological subtleties.

## State of the art of multi-component sensors and their calibration

There are countless multi-component sensor designs, each tailored to its application, and very little uniformity, for example in the testing area or in robotics. Only a few applications today allow integrated sensors, i.e. with corresponding amplification electronics, as the limited installation space of the integrated electronics may have a negative impact on the accuracy of the sensors. Apart from that, there are still not many calibration laboratories [2] that can calibrate multi-component sensors with the required precision and create a DCC with the necessary information for a smart sensor. However, with the increasing miniaturization of electronics and the increasing digital compensation possibilities, the number of possible applications is growing continuously. In general, there are still no smart multi-component sensors, even if some manufacturers describe them as such. It is up to the smart user to configure their system, controller and electronics accordingly. Today, it is not enough just to have expertise in individual specialist areas - metrological expertise is also required.

### DCC is the basis of a smart sensor

The steps that make up a smart multi-component sensor are as follows:

1. The sensor has an integrated or permanently connected (assigned) amplifier electronics
2. The electronics have one or more digital interfaces, which allows the transmission of data as well as the transmission of a DCC
3. The electronics have sufficient memory for DCC storage
4. The amplifier electronics understands the machine-readable DCC and configures itself accordingly
5. The multi-component sensor is calibrated in a laboratory, whereby the complexity of the sensor is considered and metrologically reduced to the data relevant for the application
6. The laboratory stores the cryptographically signed DCC on the sensor
7. The sensor is now plug-and-play - it spits out the metrologically evaluated data and provides the traceable calibration certificate

Of course, such systems are already in use in a similar form at some institutions. The revolutionary thing about the DCC is that the harmonization by the PTB and countless industry experts has created a globally standardized work. This provides a real basis for metrologists in calibration laboratories to competently calibrate the complex multi-component transducers and configure them using the DCC, so that the user – worldwide – does not have to make any complicated settings and is able to concentrate on its original tasks.

### Requirements on calibration procedure

Unfortunately, there are no standardized calibration guidelines for multi-component sensors. This technical area is still in a development phase. There are various approaches to calibrate the forces and moments. For a smart sensor, moment-free forces and force-free moments are of course the first choice. The calibration procedure should provide information on the contribution's resolution, linearity, hysteresis, zero-return, repeatability and reproducibility and creep, unless the sensor is used in such a specific way that individual contributions can be excluded. To carry out the calibration as closely as possible to the application, mixed loads should also be applied in addition to uniaxial loads.

*Fig. 1. Multi-component standard machine for uniaxial loading and mixed loading, performing forces moment-free and moments force-free*

### Requirements on DCC data

The certificate must contain at least the correction matrix with which the individual signals of the sensor are converted into the forces and moments. This is at least a 6 x 6 matrix, but can also be an 8 x 6 matrix, for example, if the transducer body has eight measuring bridges. And, as already mentioned, a multiple of the correction matrix may also be necessary for non-linear behavior.

A very important point for a smart multi-component sensor is the calculation of an uncertainty vector: as the forces and moments introduced are not scalar but vectorial, the calculated measurement uncertainty is also a vectorial quantity. Consequently, the DCC should also communicate the information for calculating this uncertainty vector to the smart sensor so that it calculates all measured values with the corresponding uncertainty vector.

### Conclusion

With a DCC, it is possible to have complex requirements solved by experts from the calibration laboratories, so that the sensor user can concentrate on his core tasks.

### References


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