A Brief History of Measurement System Analysis

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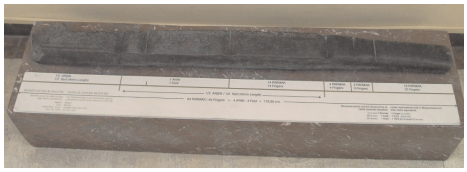
Some participants in a recently designed seminar were quite surprised by the fact that the current methods of measurement system analysis and measurement process capability analysis are really quite up-to-date. Compared to the classical SPC methods based on Andrew Shewhart's nearly 100-year-old formulas, the calculation of measurement uncertainty is still in its teens. We would like to share this discussion with you in the following article. Basically, the article only illustrates the development of these methods over time. In case of any questions, please feel free to contact the author by e-mail (Stephan.Conrad@teq.de).

Even the ancient Egyptians already had a "royal cubit master" based on the length of the Pharaoh's forearm. It was carved out of a block of granite and served as reference. They say that royal architects and foremen had to compare their cubit sticks to the royal cubit at each full moon and transfer the unit of length to the workers' instruments. It was death for them to fail to do so.

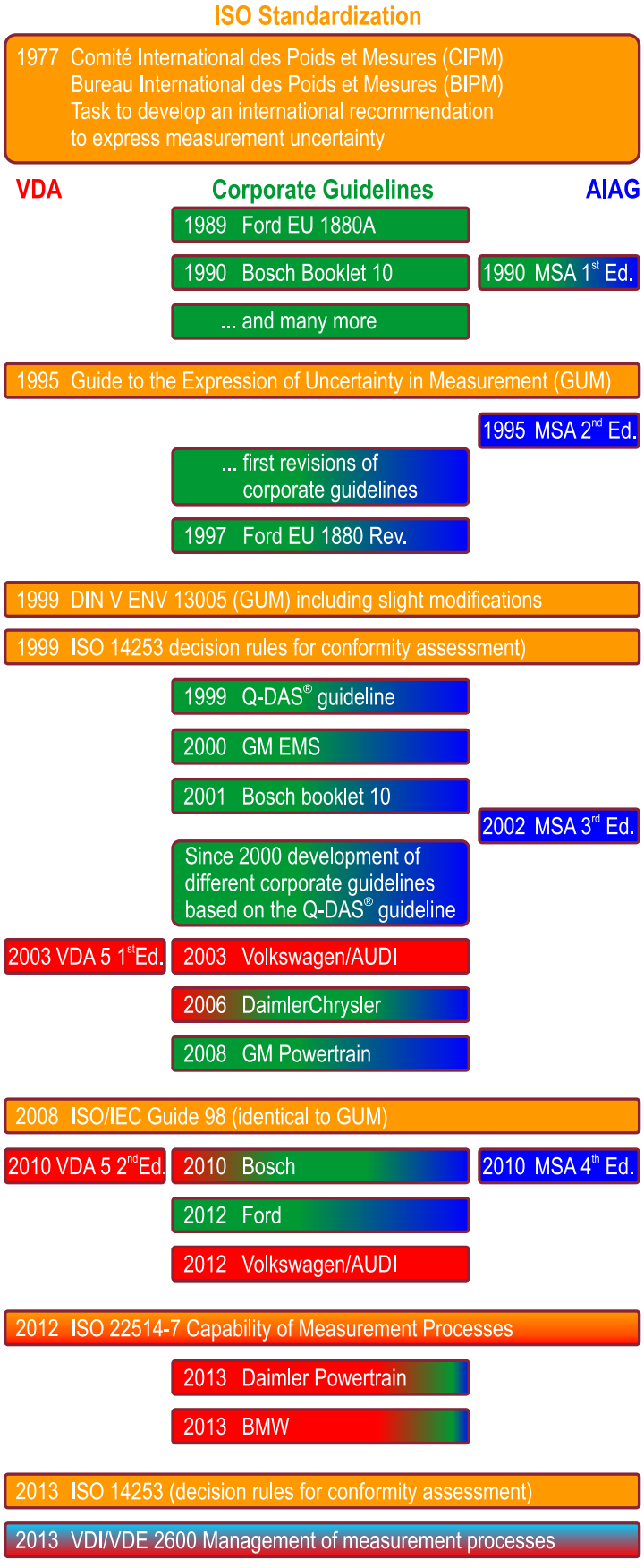


Instead of spending our time on severe punishments within the context of the first known monitoring of test equipment, we rather visit beautiful Paris, the "city of love". You can find a "marble meter bar" on several street corners. Merchants compared the length of their measuring sticks to the "marble meter" and adapted it. In 1795, Paris was the city where the first provisional meter bar (mètre des archives) was constructed of brass. The platinum meter bar was also produced there in 1799.

Finally, in 1889, a third mètre des archives was constructed out of platinum-iridium. It was the international prototype meter between 1889 and 1960. After 1960, a definition of the meter in terms of the wavelength in vacuum of the radiation relating to a transition between specific energy levels of the krypton 86 atom was adopted. This definition replaced the international prototype meter; however, in 1983, the meter became the length of the path travelled by light in vacuum during a specified time interval. All these changes since 1799 only had one goal – to increase the precision of this measure of length.

Due to the well-known problems caused in the calculation of measurement uncertainty, the international Bureau of Weights and Measures decided in 1977 to develop an international agreement on the expression of measurement uncertainty. They provided the first proposal in 1980 which was confirmed in 1981. However, it took another five years until the ISO Advisory Group on Metrology was entrusted with preparing a detailed guideline. This guideline was published in 1995 and is still known as the "Guide to the expression of uncertainty in measurement" (GUM).

If you compare the cars of 1977 to the cars of 1995, you will quickly realize that, within the scope of globalization, the automotive industry had no interest at all to wait for this standard for such a long time. In 1989, Ford published a twelve-page document for the evaluation of measurement systems. For the first time, this document described two specific test procedures – both, type-1 and type-2 study, are still known today. Other automotive companies followed suit and



Note: This diagram is not intended to be exhaustive but shows a timeline including some examples of significant events.

already in 1990, the AIAG published the first edition of the AIAG MSA manual that aimed at standardizing these methods. Even Bosch published the first booklet 10 for the evaluation of measurement systems in 1990.

In 1995, at the same time as the GUM was published and shortly after the release of QS9000, the AIAG launched the MSA guide as a reference manual to QS9000. So this document was supposed to play a leading role. However, as we all know today, the MSA did actually not succeed in replacing corporate standards. As an example, even the current 4th edition of this reference manual does not contain type-1 study, a statistical procedure that almost every company in the automotive industry applies. All the same, the corporate guidelines included more and more references to AIAG MSA.

In 1999, GUM became DIN V ENV 13005 and, based on the included method for calculating the measurement uncertainty, ISO 14253 was published for the application of the measurement uncertainty in conformity assessments.

Since the AIAG has not succeeded yet in establishing their claim for standardization, a work group with members of the automotive industry developed a guideline for evaluating the capability of measurement systems. This guideline was developed under the direction of Q-DAS® and many companies have integrated its methods into their corporate standard since then.

At the same time, the AIAG reference manual was subject of further developments. In 2002, the AIAG published the 3rd edition of the MSA manual which included significant changes. However, it still showed one of its major deficiencies – its procedures still did not consider environmental influences and influences from the test part (e.g. defect of form) in the overall evaluation of the measurement process.

So VDA Volume 5 was published in 2003 and also served as Volkswagen standard. The target of this document was an overall evaluation. While VDA members included the approach of VDA Volume 5 in their guidelines, the AIAG remained unperturbed.

In 2008, GUM was published as ISO/IEC Guide 98. The "escalation" followed in 2010. Initially, the 2nd and completely revised edition of VDA Volume 5 was published, that actually contained procedures that were easy to handle. At the same time, the AIAG released the 4th edition of the MSA manual including few, albeit fundamental modifications. International suppliers such as Bosch now faced the problem of meeting the requirements of VDA, AIAG, corporate guidelines and standardization. One of the first and earliest results was Bosch booklet 10 in 2010. Since then, one thing has led to another, even though they do not all lead in the same direction.

Ford published its new "Gauging Application Specification" guideline in 2012. This guide was less ambitious to meet the requirements of AIAG MSA 4th edition and VDA Volume 5 in detail. However, it includes specific approaches in order to determine the influence from temperature. By contrast, Volkswagen applied the 2nd edition of VDA Volume 5 as corporate standard and ISO 22514-7 represented VDA Volume 5 with slight changes.

Daimler and BMW released new guidelines in 2013. Both guidelines referred explicitly to VDA Volume 5. In addition, ISO 14253 was subject to modifications regarding the consideration of measurement uncertainty in conformity assessments.

ISO/IEC Guide 98 (GUM) ISO 14253	VDA Volume 5 (2nd ed.) ISO 22514	Corporate guidelines about MSA („what people actually do ...")	AIAG MSA 4th ed.
/IEC Guide 98 (GUM) Combined standard measurement uncertainty Degrees of freedom Expandes measurement uncertainty *"It may therefore be necessary to develop particular standards based on this Guide that deal with [...] the various uses [...]."* *"Although this Guide provides a framework for assessing uncertainty, it cannot substitute for critical thinking, intellectual honesty and professional*	Capability of measurement systems Consideration of type-1 study, linearity and other previous knowledge	Type-1 study - Cg/Cgk	Bias study (sample or QCC)
		Linearity in most cases only maximum bias)	Linearity study (significant slope and intercept)
	- Capability of measurement processes Consideration of type 2/3 study, temperature, test part, multipoint measurements, stability and other previous knowledge	Type-2 study - %GRR	Gage R&R*
		Type-3 study - %GRR	and/or ndc
		Stability	Stability *
		(No influences from environment, test part, ...)	(No influences from environment, test part, ...)
ISO 14253: Decision rules for proving conformance or non-conformance with specifications	Decision rules for proving conformance or non-conformance with specifications	No measurement uncertainty - no decision rules	No measurement uncertainty - no decision rules

The table above shows important standards and their contents as of the beginning of 2014. While the AIAG MSA reference manual still advocates methods that hardly any OEM applies ( ), specific corporate guidelines provide some sort of quasi standards the AIAG MSA does not represent. VDA Volume 5 tries to build a bridge between the standard MSA methods and international standardization. At least some parts of the automotive industry have already realized the contents of VDA 5. The VDA guidelines for calculating the capability of measurement processes cater to a standard-compliant approach for calculating measurement uncertainty. This approach also provides answers to the liability questions mentioned in ISO 14253.

Another very interesting document was also published in 2013; we are talking about the VDI/VDE 2600 guideline. It focuses on risk-based validation methods. This guideline tries to clarify whether you can validate measurement processes only individually or also in groups in order to gain representative results. This standard even contains considerably simplified approaches based on capable manufacturing processes.

Literature

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