DOI 10.5162/SMSI2025/P47

Stop ignoring units outside the SI

Joaquín Valdés[1]
[1] *Universidad Nacional de San Martín, 25 de Mayo y Francia, 1650 San Martín, Prov. Buenos Aires, Argentina*
jovaldes1875@gmail.com

Summary:
In times of digital transformation, machines are expected to operate exclusively using the International System of Units (SI), something that humans have not yet fully achieved. This requires an internationally agreed database for converting to SI units the non-SI units that humans enter at the level of human-machine interface. This contribution considers additional requirements and possibilities for achieving this goal.

Keywords: metrology, digital SI, non-SI units, conversion factors, BIPM.

Non-SI units accepted and not accepted for use with the SI

On May 20, 2025, the 150th anniversary of the signing of the Metre Convention is celebrated. There are currently 64 States Parties to the Metre Convention and 37 Associate States and Economies. At that historic moment, the goal was to ensure standard units accessible to all the people for all time. With that purpose in mind, what we know today as the International System of units (SI) was being built. The core of the constituent parts of the SI are essentially seven base units, a set of derived units and the SI prefixes. The authoritative document of the SI is the SI Brochure [1]. The SI is the only internationally agreed system of units. It was expected that such a system, which did not belong exclusively to any nation, would be adopted by all. Cumbersome conversions between the many different existing units were gradually being overcome. Despite this great achievement of humanity, not all people currently use only SI units. A relatively small set of non-SI units that were difficult to stop being used by people continued to be accepted for use with the SI. Some of those units were gradually being removed. In addition to this short list, there are still a large number of non-SI units that continue to be customary used in some contexts and countries. Let's mention some current examples of commercial transactions and industrial applications in non-SI units. Gasoline is sold in U.S. gallons (gal). In the international petroleum market prices are given in U.S. dollars per barrel (bbl). The inch (in), foot (ft) and yard (yd) are also used as units of length in several countries. Vehicle efficiency is measured in the UK in miles per gallon. Beer is commonly sold in pints (pt). Food is sold by pounds (lb). In many countries tire pressure is measured in pounds per square inch (psi). Energy associated with fuels is expressed in British thermal units (Btu). The units knot and nautical mile, until recently accepted as non-SI units for use with the SI, are still widely used in both aviation and maritime navigation. There are also laws within sovereign states allowing the use of non-SI units alongside the SI. The logic underlying the gradual elimination of some non-SI units from the SI seems to find a limit in few units, such as day, hour and minute, that humans could not stop using because they are so familiar with them. This is an inference based on the common sense of humans. The logic of interaction between machines may be quite different.

Machines operating exclusively with SI units

The coexistence of SI units with non-SI units has been the cause of many important incidents. There are known cases of overweight flights due to ground crew assuming that kilogram weight markings on cargo were pounds. The most resonant case was that of the Mars Climate Orbiter NASA´s spacecraft, which in 1999 unexpectedly crashed on arrival at its destination due to a mismatch of units. The spacecraft engineers calculated some thrust forces in pound-force (lbf), whereas the team who built the thrusters were expecting a value in newton (N), according to specifications. One solution to these problems is to continue waiting decades until all humans become familiar with using SI units. Another solution would be to force all machines to communicate with each other using only SI units. The latter has been proposed in the SmartCom project [2] with the participation of several major Na-

tional Metrology Institutes, universities and industrial companies, headed by Germany's PTB (Physikalisch-Technische Bundesanstalt). Machines use only SI units for machine-to-machine communication, while humans may still refer at the user interface level to non-SI units (Fig. 1).

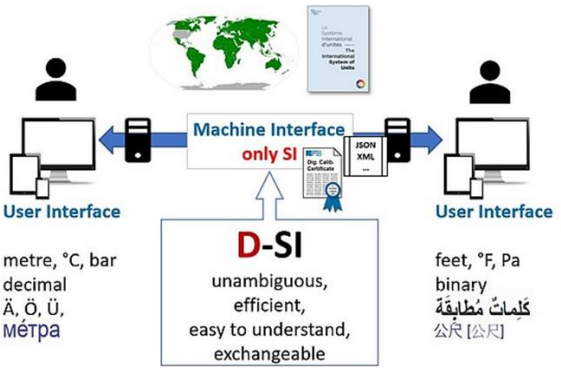

***Figure 1**: Digital SI for future machine-to-machine communication (picture from EMPIR 17IND02 SmartCom)*

The fundamental goal of this dproject is machine communication using only the seven SI base units. A unit that only requires to interpret SI base units has the greatest importance for a highly machine-readable data representation. We have recently proposed to include at the BIPM website the conversion factors to the seven SI base units of most of the non SI units used worldwide for machine-to-machine communication [3]. Here we address additional considerations in this regard.

Stop ignoring units outside the SI

The global collaboration CODATA (Committee on Data of the International Science Council) formed also in 2018 the Task Group on Digital Representation of Units of Measurement (DRUM). The title of this contribution is inspired by that of a comment article appeared in Nature in 2022: "Stop squandering data: make units of measurement machine-readable" [4]. It was published by DRUM and other scientists participating in a Forum on Metrology and Digitalization, reporting to the CIPM. The document addresses a set of shortcomings related to a consistent, machine-readable description of units in data, such as the lack of broadly agreed technical specifications for representing quantities and their associated units without confusing machines. The technical requirements for detecting the origin of the data, the units associated with the incoming data, conversion and validation modules, their language and format, so as automation of the workflow, may improve over time. However, the uniqueness of unit conversions with reference to the SI requires that a database of conversion factors be internationally agreed between States and then periodically updated with international agreement. In this regard, the information provided by the NIST Guide for the Use of the SI and the ISO/IEC 80000 series of standards would gain internationally authoritative status under the umbrella of the Meter Convention. There is already formal cooperation between BIPM/CIPM with CODATA and its Task group DRUM. It seems then very feasible that scientific efforts will continue, aiming at the inclusion of a conversion factors database in a possible international agreement between States participating in the decision-making bodies of the Metre Convention (Fig. 2).

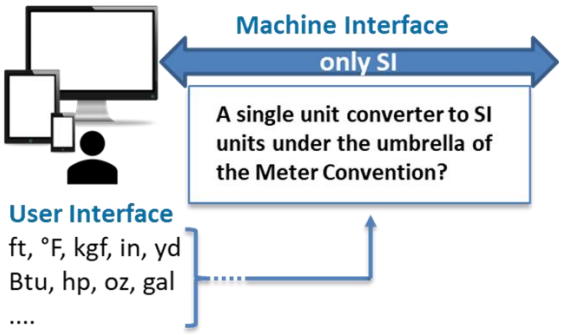

***Figure 2**: Need for a single unit converter to SI units*

Within the framework of the Metre Convention, there are already historical precedents of collaboration involving both organizations. They participate together with the BIPM in the Joint Committee for Guides in Metrology. They are also signatory of a Joint statement of intent on the digital transformation. In conclusion, the new message of universal unification emerging from those adhering to the Metre Convention could be: This is the SI, and these are the conversion factors to be used so that any other customary unit in use is discarded by using only SI units.

Acknowledgement

The author thanks to Héctor M. Laiz for helpful discussions.

References

[1] BIPM SI Brochure 9th edition 2019 (V3.01 August 2024) https://bipm.org/en/publications/sibrochure

[2] D. Hutzschenreuter et al. SmartCom Digital System of Units (D-SI), Version D-SI 1.3 (2019); doi: 10.5281/zenodo.3522631

[3] J. Valdés and H. M. Laiz, "An SI for humans and a digital SI for machines", Metrologia 62 1-5 (2025); https://doi.org/10.1088/1681-7575/ad94f8

[4] R. Hanisch et al., 'Stop squandering data: make units of measurement machine readable', *Nature* **605**, 222-224 (2022); https://doi.org/10.1038/d41586-022-01233-w