The unit one, the neper, the bel and the future of the SI

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Abstract. The 21st Conférence Générale des Poids et Mesures (CGPM) considered in 1999 a resolution proposing that the neper rather than the bel should be adopted as the coherent derived SI unit. Discussions remain open for further considerations until the next CGPM in 2003. In this paper further arguments are presented showing the confusions generated by the use of some dimensionless units, while the changes that the SI will have to face in the future are of a quite different nature.
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1. Introduction

According to the last version of The International System of Units (SI) [1], the neper, symbol Np, and the bel, symbol B, are non-SI units which are accepted for use with the SI (Table 6 of the SI brochure). As explanations to the neper and the bel, it is stated in this publication that:

"The neper is used to express values of such logarithmic quantities as field level, power level, sound pressure level, and logarithmic decrement. Natural logarithms are used to obtain the numerical values of quantities expressed in nepers. The neper is coherent with the SI, but has not yet been adopted by the CGPM as an SI unit".

"The bel is used to express values of such logarithmic quantities as field level, power level, sound pressure level, and attenuation. Logarithms to base ten are used to obtain the numerical values of quantities expressed in bels. The submultiple decibel, dB, is commonly used".

The 21st Conférence Générale des Poids et Mesures (CGPM) considered in 1999 a Resolution proposed by the Comité International des Poids et Mesures (CIPM), originated from the Comité consultatif des unités (CCU), that the neper rather than the bel should be adopted as the coherent derived SI unit. The president of the CCU explained [2] that in expressions such as that for a decaying harmonic oscillator,

$$f(t) = \exp(-\gamma t)\cos(\omega t) = \operatorname{Re}\,[\exp(-\gamma t + i\,\omega t)], \qquad (1)$$

it is customary to give the quantities γt and ωt the unit "neper" and "radian" respectively, although since the quantities are dimensionless both are actually equal to the unit one, symbol 1. It was further argued that it is not logical to include the radian, already adopted as an SI derived unit, but to exclude the neper, when both occur in a similar way in the argument of the exponential function (1).

As a number of members expressed some reservations about the proposal, it was withdrawn and the discussion remains open for further considerations until the next CGPM, which will be held in Paris in October 2003.

A revision of the arguments regarding the number 1 as a unit of the SI, conceived as the unit for the many dimensionless quantities of interest, is given in [3], including the special cases of logarithmic ratios with special names such as neper and bel. The adoption of another general name, e.g. uno, symbol U, for the unit one has been also proposed [4], with the aim to replace terms such as percent (%) and parts per million (ppm) with centiuno (cU) and microuno (μU). Some concerns over those arguments were published [5, 6] later.

The mathematical logic supporting the preference of the neper as a coherent SI derived unit instead of the bel was thoroughly presented in a contribution by three members of the CCU [7]. Based on the contents of that paper, during the 90th meeting of the CIPM (Sèvres, 10-12 October 2001) a slightly reworded version of the resolution presented to the 21st CGPM was aproved as CIPM Recommendation [8], with one abstention and one vote against, the latter corresponding to the author of this paper.

A new approach based on a redefinition of the quantities underlying the units neper and bel, gave rise to a CCU Recommendation U1 (2002) adopting both special names for the number one as coherent derived SI units. The neper would no longer be used to express levels, as stated in the SI brochure, it could now be defined as SI derived unit for natural logarithmic amplitude ratios corresponding only to pure (single frequency) sinusoidal functions and the bel, used for logarithmic ratio quantities, to the base ten, called levels, where no single frequency and no amplitude can be defined for the quantities concerned.

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More arguments concerning these discussions prior to the 22nd CGPM are presented here.

2. Quantities and units, neper vs. bel.

The question of units corresponding to logarithmic quantities is in fact a matter originating several decades ago, at the beginning of the cooperation between the International Electrotechnical Commission (IEC) and the International Organization for Standardization (ISO). At that time there was a conflict, because ISO preferred natural logarithms and IEC decimal logarithms [9].

In the Foreword of the ISO Standards Handbook on Quantities and Units [10], which includes the 14 parts of the International Standard ISO 31 and the ISO 1000, the Secretariat of ISO/TC 12 states that “The SI is coherent with respect to a corresponding system of quantities. The system of quantities, on which the SI is based, is not within the scope of CGPM. This question is handled by the ISO Technical Committee ISO/TC 12, *Quantities, units, symbols, conversion factors*”.

Metrology dealt with quantities and related units before the existence of the ISO and formally through the CGPM since 1875 when the Meter Convention was signed. The mission of the CGPM is to discuss and adopt necessary measures for the propagation and development of the Metric System, and to sanction new fundamental metrological determinations achieved during the years between meetings (Meter Convention, Article 7). The ongoing discussion is the best example that it is impossible to consider quantities and units separately, something especially evident after the proposal to redefine the quantities to which the units neper and bel may correspond. It is clear that the CGPM should not restrict the discussion of adopting the neper or the bel, both of them, or none of them, as SI units of quantities without considering the meaning of the quantities themselves.

According to the International Vocabulary of Basic and General Terms in Metrology [11]: *A (measurable) quantity is an attribute of a phenomenon, body or substance that may be distinguished qualitatively and determined quantitatively. A unit of measurement is a particular quantity, defined and adopted by convention, with which other quantities of the same kind are compared in order to express their magnitudes relative to that quantity. Symbols for quantities are given in ISO 31.*

In the Annex A (informative) of the ISO 31-0 International Standard, the meaning of “levels” is stated as follows: The logarithm of the ratio of a quantity, $\boldsymbol{F}$, and a reference value of that quantity, $\boldsymbol{F}_0$, is called a level. In the ISO 31-2 standard, item 2-9, the level of a field quantity is considered a quantity itself, denoted with the symbol $\boldsymbol{L_F}$, unit neper or bel, symbols Np and B respectively.

Irrespective of the base to which the logarithm is considered, even irrespective of the logarithmic operation itself, if we adopt a unit for a given quantity and another reference value of that quantity to establish “levels” of the same quantity, we introduce two different values (particular quantities) to compare quantities of the same kind and express their magnitudes relative to a particular quantity. For instance, when we measure pressures relative to the SI unit pascal and we measure pressure “levels” in dB relative to 20 μPa, the smallest value to which human hearing is sensitive, a confusing situation similar to the adoption of two different units for quantities of the same kind appears. It is even recognized by experts of acoustical metrology that the consequences of a decibel scale is confusing and that decibel representations can be avoided by simply converting all levels to the underlying physical quantities [12].

This is an intrinsic disadvantage, which is valid both for the bel, or the decibel, as well as for the neper; more important than considering which of both is coherent and the base to which the logarithmic operation is defined. Introducing now the neper as an SI unit will contribute to increasing the confusion that already exists with the decibel, wether corresponding both units to similar quantities or even accepting the stratagem of dividing signals into pure and non pure, assigning the bel to levels in general and the neper to logarithmic amplitude ratio quantities used only for pure sinusoidal signals. Fixing the frequency in one value may simply correspond to a special case of the same quantity used to define the general case, without implying different units, just as the same SI unit is valid for alternating current and for direct current, where DC may be seen as a special case for zero frequency. Moreover, pure harmonic oscillators do not exist in practice. Even theoretically considered, a pure DC signal is fictitious because a time window always exists. The same is valid for a “single frequency” sinusoidal signal. The convolution of a “pure” DC signal with the corresponding time window, calculated e.g. using Fast Fourier Transform in order to obtain the frequency spectrum, wether the time window be as small as a fraction of a second or as large as the age of the universe, result in a set of frequency components besides the main signal at zero frequency [13].

With the actual definition of the neper and related quantities, there was a certain general agreement that the addition of the neper to the SI would be a logical step, although probably with not much practical impact [8]. After the newly proposed definition it would have still less impact or perhaps none, only adding to more confusion.

3. The unit one, one radian, one neper, one bel and one uno.

In order to avoid adding more confusion to the matter of discussion in this paper, as the word "quantity" accepts different meanings in English, in some sentences it will be followed here by the French word *grandeur* in brackets, when it is used as defined in the International Vocabulary [11].

There are a large number of dimensionless quantities (*grandeurs*) which have not yet received a special name. We may ask ourselves if it is convenient to consider them as quantities (*grandeurs*), assigning special names to their common unit one in specific contexts, and even another name common to them all for general use, e.g. uno.

When we were still babies, our parents devoted a lot of efforts to familiarize us with the number one. We learnt to answer the question "How old are you?", first saying "one", after some time "two", then "three", showing respectively one finger, two fingers, three fingers, and so on. We incorporated the concept of counting, starting by one, and in some manner also a first knowledge of measuring time, in connection with our own age. Later we learnt to count from "one to ten" and even more, always referred to the base ten because we have ten fingers, but just counting numbers. Adding 2 plus 3 was equivalent to counting how many times the number one was included in both numbers, counting one after the other. Multiplying 2 by 3 was equivalent to adding 2+2+2, and calculating $\log_2 8$ was the same as counting how many times the number 2 has to be multiplied by itself in order to get 8.

Now we just enter numbers in an electronic calculator, where counting is an internal process leading to the results of the most complicated mathematical operations almost instantaneously, including changes in the basis for logarithmic operations. Even the computing basis for counting and making calculations is not decimal. Nevertheless, the advance in binary computational facilities did not affect the essentials of the decimal metric system, until now. This is an argument that measuring is something different from just counting abstract numbers or doing mathematical operations on different basis.

The logic of considering the ratio of two quantities as a new quantity is the following: Consider e.g. the quantity mass. Adding two masses m_1 and m_2 we obtain again a mass. Multiplying m_1 by m_2 we obtain a new quantity (grandeur) in square kilograms. Conversely, dividing m_1 by m_2 we should also obtain a quantity (grandeur). Why should division be a special mathematical operation leading to no quantity at all?. It is a matter of choice. One may also argue that dividing one quantity by other of the same kind merely express the number of times one quantity fits into the other. This number may be just called a coefficient, a factor or a ratio, but not a new quantity. On the other hand, with the current logic dimensionless quantities obtained by division of two quantities of the same kind, present properties different from other quantities (grandeurs). For instance, we can add units of the dimensionless quantity plane angle like rad + rad^2 + rad^3, but we can not do the same with the unit of mass kg + kg^2 + kg^3.

As the CGPM already decided to adopt the radian as the coherent SI unit of the dimensionless quantity plane angle, following the same logic the adoption of other SI units with special names such as the neper and the bel, different from the name "one", for other dimensionless quantities is being proposed.

The situation with the radian, defined as the ratio of two lengths, is a somewhat particular case, because people acquire already at the primary school a concept of plane angle which differs from the concept of length. But let us see what could happen if we continue expanding this logic to the ratios of other quantities. Let us come back to the ratio m_1/m_2, also called mass fraction. Considering it as a dimensionless quantity, the corresponding SI unit is kg/kg = 1. As in the case of the radian, or the proposed neper, we might give a special name to kg/kg, for instance sèvres, symbol Sèvres. Consider now an example where 1 kg of pure copper was produced, and 300 g were used. We may say that 0.3 kg of copper, or 0.3 sèvres of pure copper have been used. The introduction of the unit sèvres would then lead to confusion with the already existing base unit kg.

The same confusion would appear giving a name to a power level expressed in watt/watt, or to the pressure level expressed in pascal/pascal. As already mentioned in paragraph 2., this confusion will be still greater if different dividers are defined as reference thresholds for each level, such as 1 pW or 20 μPa, the smallest power and pressure to which human hearing is sensitive.

Confusion may be still greater when the same unit is assigned to a great quantity of dimensionless quantities (grandeurs), as it is the case of the decibel. One may use the decibel with different power and field quantities [14], such as dB(mW), dB(W), dB(0.775V), dB(V), dB(mA), dB(μV/m), dB(W/m^2), dB(W/4kHz), dB(W/K), dB(W/m^2kHz), dB(kHz), dB(Pa), dB(Pa/V), dB(mV/Pa) and dB(K^{-1}). Despite in fact that the SI brochure recommends that "in using the neper and the bel it is particularly important that the quantity be specified", the quantities in brackets are seldom written and users have problems in understanding technical specifications expressed in dB.

If the analogy of the radian goes on expanding to other fields, assigning special names like neper or bel to dimensionless quantities which appear in the same equations together with angles, and then to others which may appear in more equations for certain contexts together with the radian, steradian, the neper or the bel, we open the door to a logic which may be very dangerous for the health of the world's measurement system. In order to get an idea of the many dimensionless quantities which some day might become new candidates to receiving special names for some mathematically logical reason, the following list corresponds to those quantities included in the ISO Standards Handbook Quantities and Units [10], with unit one, symbol 1:

Mechanics: relative volumic mass, relative mass density or relative density, linear strain, shear strain or volume strain, Poisson ratio or Poisson number, dynamic friction factor, static friction factor, efficiency.

Heat: ratio of the massic heat capacities, ratio of the specific heat capacities, isentropic exponent.

Electricity and Magnetism: relative permitivity, electric susceptibility, coupling factor, leakage factor, relative permeability, magnetic susceptibility, number of turns in a winding, number of phases, phase difference (also radian), quality factor, loss factor, loss angle (also radian), power factor, Gaussian permitivity, Gaussian electric susceptibility, Gaussian permeability, Gaussian magnetic susceptibility.

Light and related electromagnetic radiations: emissivity , spectral emissivity (emissivity at a specified wavelength), directional spectral (emissivity), photon number, luminous efficiency, spectral luminous efficiency, luminous efficiency at a specified wavelength, CIE colorimetric functions, trichromatic coordinates, spectral absorption factor, spectral absorptance, spectral reflection factor, spectral reflectance, spectral transmission factor, spectral transmittance, spectral radiance factor, optical density, refractive index

Acoustics: dissipation factor dissipance, reflection factor reflectance, transmission factor transmittance, absorption factor absorbance.

Physical chemistry and molecular physics: Relative atomic mass, relative molecular mass, number of molecules or other elementary entities (confusion with the SI base unit mole!), mass fraction of substance B, volume fraction of B, absolute activity of B, standard absolute activity of B (in a gaseous mixture), activity coefficient of B (in a liquid or a solid mixture), standard absolute activity of B (in a liquid or a solid mixture), activity of solute B, relative activity of solute B (especially in a dilute liquid solution), activity coefficient of solute B (especially in a dilute liquid solution), standard absolute activity of solute B (especially in a dilute liquid solution), stoichiometric number of B, standard equilibrium constant, microcanonical partition function, canonical partition function, grand- canonical partition function, grand-partition function, molecular partition function, partition function of a molecule, statistical weight, thermal diffusion ratio, thermal diffusion factor, proton number, charge number of ion, degree of dissociation, transport number of ion B, current fraction of ion B.

Atomic and nuclear physics: proton number, atomic number, neutron number, nucleon number, mass number, g-factor of atom or electron, g-factor of nucleus or nuclear particle, orbital angular momentum quantum number, spin angular momentum quantum number, total angular momentum quantum number, nuclear spin quantum number, hyperfine structure quantum number, principal quantum number, magnetic quantum number, fine- structure constant, relative mass excess, relative mass defect, Packing fraction, binding fraction, Internal conversion factor.

Nuclear reactions and ionizing radiations: total ionization by a particle, resonance escape probability, lethargy, average logarithmic energy decrement, neutron yield per fission, neutron yield per absorption, fast fission factor, thermal utilization factor, non-leakage probability, multiplication factor, infinite medium , multiplication factor, effective multiplication factor, reactivity.

Solid state physics: order of reflexion, short-range order parameter, long-range order parameter, Debye – Waller factor, Grüneisen parameter, Madelung constant, Mobility ratio, Landau – Ginzburg number.

This list is not exhaustive. The SI brochure in 2.2.3 makes reference to other quantities having the unit 1, e.g. “characteristic numbers” like the Prandtl number $\eta c_p/\lambda$ and numbers which represent a count, such as number of energy levels. We may argue if all these ratios, functions, numbers, factors, parameters, constants, coefficients, indexes, exponents or coordinates are really quantities in the sense defined in the International Vocabulary [11]. The fact is that they already have a unit assigned, all of them the same unit, it is the unit one, symbol 1, and it has been proposed to change the name one by the name uno [4], which is just the translation of “one” into Spanish and Italian.

Appendix 2 of the SI relates to the practical realizations of the definitions of some important units. All the units, even if they are not so important as those considered in Appendix 2, have also to be realized. Therefore, we may ask how will the realization of the uno be put into effect?.

In the world of metrology the realization of a unit in conformity with the corresponding SI definition implies measurements. Therefore, the realization of a counting number does not sound in principle as something concerning metrology. Nevertheless, not only the unit one results from ratios of quantities (*grandeurs*) of the same kind. The value of π is also obtained as the ratio of the length of a circumference to the length of its diameter. This means that π is a number which may be obtained from measurements. One may regard π as the value of a ratio obtained when measuring an angle, regardless of the unit of length, regardless of any length standard, regardless of time and regardless of the local point where the measurement is done. This is the reason why the number π may even be considered a constant of nature [15]. Perhaps a definition of the unit for a plane angle referred to π could have been more in agreement with the actual trend of defining units based on fundamental constants.

Regarding the number one as a unit of measurement, a lot of different realizations will correspond to the realization of the uno, as it would be the unit of a lot of different quantities (grandeurs). The best realization of the uno corresponding for instance to the dimensionless quantity mass fraction would be achieved with a prototype balance, comparing two 1 kg mass standards. But this is something that has already been done, e.g. in the "mass laboratory" at the BIPM, where nobody is thinking of replacing its name by "laboratory for the realization of the uno", or "laboratory for the realization of the sèvres".

Perhaps the implications of adopting names for the unit one are not seen dangerous for the SI because it is thought that they will produce no dramatic change and the SI is already well established. But we should not forget that in some countries where old units are still competing with SI units many people would celebrate a self-inducted generallized confusion within the metric system. Other potential dangers are also present against a unified measuring system, caused by attempts to change the rules for particular applications in special contexts. For example, a well-known company manufactures watches with a new concept of universal time, called INTERNET time. This system with no time zones, promotes a new meridian reference in Switzerland instead of the Greenwich meridian. This concept of "new time scale", intends to satisfy INTERNET users with a common time everywhere, be it night or day. The idea is really not new. It was already considered and rejected when the International Conference of the Hour decided to adopt the actual time zones.

Therefore, splitting hairs adopting SI units and special names for units of dubious need does not seem to be the best way to improve the SI.

4. The future of the SI.

We have seen that not every logical step constitutes the best way to improve the SI. This is as much applicable to a mathematical logic as to a physical one.

Let us consider the Boltzmann constant k, which relates energy and temperature through the molecular energy equation $E = (3/2)kT$. In a similar way, one may consider the equivalence of energy and other quantities (*grandeurs*), because of the proportionality existing through fundamental constants of different origins. For example energy and mass are related through the velocity of light c by the Einstein equation $E = mc^2$. Energy and frequency are related by $E = h\nu$, where h is Planck's constant and ν the frequency of a photon. Energy and electric potential difference U are related through the quantum of electrical charge e by $E = eU$.

Looking at these equations we see that the international measuring system could be quite different from the actual one. It should be possible to maintain a single standard system with only one quantity (grandeur) taken as basic. It should even be possible to build a consistent system of measurements with no standard at all, just assigning the number one to a set of fundamental constants [16]. Such systems would be very beautiful for theoretical work, but the measurement precision would not be nowadays satisfactory for an expanding industry and even for the experimental work needed to discover physical laws, verify physical theories and develop new technologies.

Future changes in the basis of the measurement system should not be determined only by the logic of the equations of physics. We live in a world of measurements, where people already identifiy concepts with words attached to them in the daily language. Even when it should be possible to refer the whole measuring system to only one quantity (grandeur), and this may be useful to understand physics, our daily life would turn quite difficult in such a case.

The present definition of the metre as the length of the path travelled by light in vacuum during a certain time interval determined by the speed of light is quite understandable, because people already use the same concept with other velocities. When somebody is asked how far the cinema is and answers a 15 minutes-walk, or 2 minutes by bicycle, a question of length is answered in terms of time assuming a given velocity. Quite different would be the situation if one refers all the quantities (*grandeurs*) to time. For instance, speaking of mass in terms of seconds will not sound right. Stating the energy equivalence through Einstein and Planck's equations $mc^2 = h\nu$, the conversion factor of kg into s is given by $kg.s = h/c^2$. With the actual values of the fundamental constants c and h, if someone wants to reduce his mass in 10 kilograms, he would have to say "I am too fat, my weigth should be 14.10^{-54} seconds more". Therefore, this kind of "logical step" has to be discarded, because it is not suitable for the purpose of a unified system of measurements accepted worldwide.

The world that human beings developed needs access to ever more accurate measurements [17]. The advancements in nanotechnology, opening possibilities to count and control elementary particles one by one, will also impact on metrology and the precision with which fundamental constants are known. Consider the mole, for example. This base unit is a number. In principle it is not easy to accept defining a base unit by a number. Nevertheless, the mole is at least not merely an abstract number like the number 1. The mole is the SI unit corresponding to the base quantity “amount of substance”, defined as the number of atoms in 0.012 kg of the pure isotope carbon-12, although analytical experiments do not generally use carbon-12 atoms. One might say that the definition of the mole includes the Avogadro constant. Such great numbers of elementary entities are compared actually by chemical means, because of our inability to count the particles one by one.

After the emerging revolution of nanotechnology, new incursions in the microscopic world are already available, allowing management and counting of atoms one by one [18]. The time needed to gather a considerable quantity of atoms picking them one by one may be too much, if the purpose is to build a structure that will be useful as standard. Nevertheless, promisory experiments are being carried out for non-metrological purposes, obtaining well-defined, self-organized molecular systems, where nanostructured plates are stacked with a common direction by self-assembly [19]. Replicating such structures may lead to a considerable amount of matter with a well-established number of atoms.

Advances in nanotechnology also allow counting electrons one by one and conducting them by nanowires [20]. It should also be possible to engineer an electrically driven single photon source [21]. Generating and counting phonons one by one also seems feasible in the near future [22, 23].

Approaching quantum limits is giving rise to new devices, like nanoscale mechanical resonators and electrometers [23-24] or cillia microphones constructed with carbon nanotubes, imitating the cillias in the human ear [25]. This technological revolution may lead to new realizations of the SI units with improved accuracy.

5. Customer focus.

SI units are what they are defined to be until new practical developments make some change preferable [26]. But the user of units must also find them ultimately convenient, otherwise they will not be used [27].

Users of the SI are the goverments, professionals, scientists and technicians, metrologists among them, manufacturers, suppliers, traders, end users, consumers and citizens in general. Before introducing changes in the SI, and following recommended best quality practices of customer focusing, it would be convenient to know the opinion or possible reactions of the users of the SI, the benefits or disadvantages and the social and economical impacts associated with them.

Concerning the unit bel, it is particularly difficult for the many millions of consumers to decide which musical equipment is better for their purpose, which loudspeakers are best intended for the different amplifiers, compact disc players, or DVD systems, when some specifications included in the equipments instruction handbooks are expressed in watts and others in all the ratios that decibels may imply, mostly without quoting the quantities to which decibels are referred. On the other hand, people already have a thorough idea of what decibels mean, as a measurement unit related to the volume of sound or speech. When a discussion is getting heated, it is usual to say “let’s bring down the level of decibels”. Therefore, it is no longer possible to suddenly start ignoring the bel (decibel).

Regarding the adoption of the neper as an SI derived unit, justifying this because “there is a need”, or “it proves convenient”, one should ask for whom it is convenient or why there is a need to do so. Coherence in the metrological meaning may be a requirement stated by metrologists, but also coherence in the sense of not confusing end users is a major requirement to be taken into account. If the consequence of maintaining mathematical coherence is that most of the customers, i.e. citizens and consumers in general, will be confused, a decision has to be taken focusing on one or another SI user.

The neper has been used for many years, although it has not seen frequent use. Even the opinion of the CCU is that “changes to the SI should be kept to a minimum, and should only be made when there are very strong reasons for change” [2].

6. Conclusions.

The best recommendation should be to use more the accepted SI units underlying such ratios or levels as bel or neper.

Adopting special names for other dimensionless quantities, even another general special name for the number one, will add more confusion to that already existing. The best solution in order to preserve the health of the SI and avoid expanding confusion is that all these superfluous units of dimension one do not receive special names and remain unnoticed.

Those metrologists or groups of SI users who already know what they are speaking about may go on living with the usual concepts of “gain factor of 10”, “decay factor of e”, “voltage ratio”, “current ratio”, power ratio”, etc., without the need to write a unit, which otherwise is almost never written. The same applies to the recommendation of insisting with the use of µV/V, µg of substance A per kg of substance B, etc., instead of ppm, without introducing new names like "microuno", which could be a cause of major confusions for the whole community of SI users.

Changes in the SI may only be introduced when it is quite clear that they will represent an advantage without bringing confusions to the society. Logical steps have to be confronted with their acceptance by most of the SI users. Future significant changes in the SI will be mainly related to technological advancements. Nanotechnology opened the door to a new technological revolution, as already predicted more than 30 years ago by Richard Feynmann in his famous lecture entitled *"There's Plenty of Room at the Bottom"* [28]. Approaching quantum limits and manipulating elementary particles one by one will determine a new instrumentation and important changes in the SI. Old discussions such as those concerning dimensionless quantities and logarithmic ratios are less important than the changes the SI will have to face in the near future.

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