Dear Ted and Ron,

Thanks for your interest in the electronic kilogram. I'll try to answer your questions.

> Dear Dr. Steiner,
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> We (Ted Hill and I) read with interest the 4/17/08 Los Aangeles Times article
> on the kilogram, and would like to ask you three concrete questions about your
> proposal to redefine the kilogram.
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> 1. What is your proposed definition of the kilogram, such as it would appear
> in high school and college physics and chemistry texts?

There are various ways the redefinition might look, and they don't have to be readily tied into the method of measurement. One way we have mentioned relates the de Broglie quantum energy equation $E=hf$ to Einstein's $E=mc^2$. Thus, $m=hf/c^2$. An appropriate frequency, f, is chosen to make the new kilogram unit equal to the present kilogram artifact, relative to the assigned values for h and c. In the future, with that frequency now chosen, the artifact may no longer equal 1 kg. The watt balance would measure mass in terms of a frequency standard, along with fixed constants for Planck, h, and the speed of light, c. The particular frequency in this equation is very large and does not have any real physical meaning; it is just a definition constant. The electronic kilogram essentially makes an energy measurement related to the gravitational force on a kilogram; we do not measure the conversion energy of a kilogram of mass.

There are other definitions that would be equally valid, although there is some added convenience in using a definition based on the Planck constant, since it is fundamental in using the Josephson effect as a quantum, intrinsic standard for voltage.
>
> 2. Would your definition of kilogram guarantee that the Avogadro's constant is
> an integer? What integer value is implied, if any?

Any redefinition based on present data would assign the Planck constant to 8 digits. The Avogadro integer value would be at the 24th digit. (Derivations of Avogadro from other constants using certain mathematical methods might result in fractional indefinite values, but those fractions are understood as far less than the uncertainty in assigning the original constant.) Under the present uncertainty in the kilogram artifact, those last 16 digits in Avogadro are uncertain. A related value for Avogadro would also be assigned as 8 digits. Whether data for the assignment is chosen from watt balance techniques or x-ray crystal counting techniques will depend on the confidence in either technique. Atomic mass measurements of atoms is very precise relative to carbon 12, but scaling from the kilogram artifacts to the atomic level or vice versa has a large uncertainty.

I don't know off hand what the Avogadro constant might be, although we did calculate it for the 1998 result.

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> 3. Exactly how different (e.g., means and uncertainties) are your watt-balance
> results from the British team's watt-balance results? How should the two data
> sets be consolidated, and what would be the theoretical justification for your
> proposed method of consolidation?
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The NPL value came in at just about 300x10^-9 +/- 51x10^-9 difference from the NIST values, and from the NPL value of 1988. The most recent NIST value had a 36x10^-9 uncertainty. The NPL value is between the NIST value and the Avogadro value, which is 1000x10^-9 higher with an uncertainty of about 200x10^-9. We do not yet know why there are discrepancies between the various results. Consolidating the results for a CODATA estimate of the constants is a statistical weighting problem the CODATA team needs to worry about. A similar analysis will eventually be performed to obtain a defined value for the Planck constant, but the values will have to be much better matches.

The international committee in charge of defining the units will not likely redefine anything until at least two laboratories produce results that overlap with uncertainties approaching 20x10^-9. We might hear about a tentative result from the Swiss in another month, and from the French in another year or two.

Any "theoretical" justification for redefinition debatably may or may not rely on the accuracy and precision of the method chosen to reproduce a commercially applicable kilogram standard. A number chosen as a near match to existing data would theoretically work just as well as a system of standards. However, the standards community does tend to dislike applying corrections to units and artifact values when the assigned constants as chosen are based on inadequate measurements. As measurement techniques improve over time, more digits can be measured and errors can arise from either an ill assigned value with exaggerated uncertainty or simply more resolution from improved uncertainty.

Check the history on the assignment of the Josephson constant. Different countries assigned different values, because their maintained group of standard cells was considered the "right" value, and thus different constants were needed to make their volt the "correct" volt. It was eventually realized that standard cells were drifting more than thought, and generally in the same direction, so over time, no group of standard cells was "correct" relative to the SI measurements relating the volt to other units. At the time in 1972, 1x10^-7 was considered sufficient uncertainty. National volts based on groups of standard Weston cells were eventually found to differ at several parts 10^6. Thus, in 1990, different countries had to apply different corrections to their volt. The USA correction was 9.2x10^-6. There were several instruments available that advertised calibration accuracy to 4x10^-6, so these instruments were suddenly out of cal.

It is important that the kilogram and Planck constant be consistently and accurately assigned. Otherwise, a mechanical measurement of power (relying on the kilogram) would be different than an electrical measurement of power (relying on the Planck constant). This is the basis for the watt balance, i.e. electronic kilogram, experiment. If the uncertainty in the measurements used to define the constants is understood with confidence to be within 20x10^-9, then the electronic kilogram should keep the uncertainty of the commercial realization of the kilogram as related to the SI at that level for decades and more. Ultimately over time, almost all the constants are likely to be redefined, but it is hoped by adding more digits rather than changing the existing significant ones.

Again thank you for your interest.

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> Thank you for your time.

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> Our interest is highlighted in
> http://www.gatech.edu/newsroom/release.html?id=1513
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