Episode Book

EPISODE #6252

How the Kilogram Leaves the Basement

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SYNOPSIS

Fixing the Planck constant redefined the kilogram in 2019, but turning an abstract mathematical definition into a reliable measurement still requires complex machinery and physical transfer standards. Metrology laboratories navigate the practical reality of realizing mass with Kibble balances and silicon spheres. Experimental trade-offs, parasitic coil motions, and international comparisons between national metrology institutes show how collective consensus bridges pure physics with everyday precision weights.

TRANSCRIPT



Corn

I find the continued employment of the kilogram rather reassuring.



Daniel

What I want to understand is what happens after you define a unit using a constant. Someone still has to make a measurement that everyone else can use. Who actually does that, what are they working with, and how does it eventually reach a shop scale or a torque wrench?



Herman

There is still an extraordinary amount of metal involved. The definition changed in May twenty nineteen, but nobody sent a supermarket a copy of the Planck constant and wished them luck.



Corn

The publicity made it sound as though the cylinder had retired and mathematics had taken its shift.



Herman

Mathematics supplies the definition. Laboratories supply a realisation, an experiment that produces measurements consistent with that definition. Then other laboratories transfer those measurements into useful reference standards. Those are separate jobs, and the last one is where much of the actual work lives.



Daniel

I want to keep that physical. If I walk into one of these places, am I looking at a special weight, a machine, or a person spending a morning checking something?



Herman

All three, frequently in the same room. Although the person might spend the morning discovering why yesterday's measurement no longer agrees with today's.



Corn

An exact constant. An approximate Tuesday.



Herman

Consider the kilogram. We fix the numerical value of the Planck constant, which connects energy and frequency. With the second and metre already defined, that fixes the kilogram too. It does not give a machinist dimensions for a perfect weight.



Corn

Nor does it tell him whether his finished weight has acquired a fingerprint.



Herman

The recognised primary methods are the Kibble balance, which connects mechanical measurements with electrical ones, and X-ray crystal density, usually called XRCD. That second route uses a crystal to relate a macroscopic mass to the mass of an atom of a specified isotope. Both can reach uncertainties of a few parts in a hundred million.



Daniel

Who decides that someone's machine has succeeded? Could a university build one and declare that its kilogram is the kilogram?



Herman

It can build an experiment. Establishing that other people should trust the result takes comparisons, uncertainty analysis, and institutional scrutiny. The BIPM coordinates internationally, from the Pavillon de Breteuil in Sèvres, near Paris. It has sixty-seven member states. National metrology institutes operate the primary realisations and calibration services.



Corn

NIST in America, PTB in Germany, LNE in France, NMIJ in Japan. Not a single international weight room with every country's coat hanging outside.



Herman

There are different capabilities in different countries. Some institutes realise a unit directly. Others obtain calibrated standards from an institute that can. The BIPM also calibrates standards for national institutes without their own primary kilogram realisation.



Herman

Corn, would you trust the independent machine more, or the carefully maintained weight arriving from another laboratory?



Corn

For daily work, the weight. For finding out whether all our carefully maintained weights are drifting together, the machine. I wouldn't want the expensive experiment performing every routine comparison.



Herman

That division is very close to how the system actually operates. Primary experiments establish values. Durable transfer standards let everyone else get some work done.



Daniel

What actually changed in twenty nineteen beyond the kilogram? I associate the announcement almost entirely with that cylinder.



Herman

Four units received new definitions. The kilogram through the Planck constant, the ampere through elementary charge, the kelvin through the Boltzmann constant, and the mole through the Avogadro constant. The whole SI is now organised around seven defining constants. We retain the familiar base units, but the constants supply the structure.



Corn

The important advantage is that you can improve the experiment without negotiating a new kilogram. An artefact limits you to whatever that particular artefact is doing. A definition tied to a constant allows a better machine to replace your present one.



Herman

Including a machine nobody has invented yet. That's exciting.



Corn

I knew you'd prefer the unbuilt machine.



Herman

It has excellent specifications so far.



Daniel

Take the existing one, then. What would I see at NIST?



Herman

NIST-four stands about as tall as a walk-in closet, in a basement laboratory at Gaithersburg. It includes a precision balance, a magnet and coil, optical measurements, electrical standards, and a vacuum system. You put a mass on it, but the point is to connect that mass to electrical quantities you can establish through quantum effects.



Corn

Basement, vacuum chamber, walk-in closet. The kilogram has downsized into a difficult flat.



Herman

Two operating modes do the clever part. In weighing mode, current through a coil in a magnetic field produces an upward force that balances the weight. But the exact force depends on the magnetic field and the effective wire length. Those are awkward quantities to know accurately enough.



Daniel

That's the part I would have assumed was the whole machine. A very sophisticated electromagnetic scale.



Herman

The second mode removes that difficulty. You move the coil through the magnetic field and measure its speed and the voltage generated. The same magnetic field and wire geometry appear in both modes. Combine the results and that shared factor cancels.



Corn

Provided the geometry really is the same. You look very happy whenever an awkward term disappears, Herman. I assume the apparatus has opinions.



Herman

Strong opinions. The cancellation depends on how well the two measurements represent the same system. You also need local gravitational acceleration. The balance measures weight as a force, then infers mass. It cannot simply assume that gravity in its basement is an exact universal number.



Herman

The voltage is linked to Josephson junctions. Current is determined using a resistance tied to the quantum Hall effect. Those electrical measurements connect back to the defining constants, including the Planck constant.



Daniel

Where does it actually struggle? Not in principle, but on the laboratory bench?



Herman

At the BIPM, the recent comparison gave their balance a standard uncertainty of thirty-six micrograms on a kilogram. Previously it was forty-one. Much of the improvement came from aligning the interferometer laser more accurately with the vertical.



Corn

Five micrograms recovered by pointing properly.



Herman

Their largest remaining uncertainty contribution is parasitic coil rotation during the moving phase. The coil rotates slightly when they want it to move vertically. A beautiful quantum connection still depends on controlling an unwanted mechanical motion.



Corn

This is your archery lecture with a vacuum pump.



Herman

My archery lecture would also benefit from someone measuring whether I actually stand straight.



Daniel

Does the crystal method avoid all that, or does it have its own equivalent of a crooked coil?



Herman

Its own demanding measurements. With a highly characterised silicon crystal, you determine how many atoms occupy a measured volume and relate that to mass. The lattice spacing, the external volume, the isotopic composition and surface layers matter. You're exchanging one set of experimental difficulties for another, not escaping experimental difficulty.



Corn

Which is useful. Two machines making the same unnoticed mistake would be less reassuring than two very different methods disagreeing openly.



Herman

Ten institutes participated in the latest key comparison. Most used Kibble balances, China used a Joule balance, and three used XRCD. The independence matters when you decide whether a result reflects the unit or a particular apparatus.



Daniel

Are those results now close enough that everyone simply uses whichever machine is nearest?



Herman

Not yet. The definition is fully in force. Its practical dissemination remains in a transition. Since twenty twenty-one, the Consultative Committee for Mass has used a consensus value derived from primary realisations because the independent results had not agreed closely enough.



Corn

The definition doesn't go to a vote. The best present estimate of how to deliver it does require collective judgement.



Herman

The third consensus value took effect on March first. It differs by minus five micrograms from the previous value, and minus twelve micrograms relative to the historical prototype-based kilogram.



Daniel

Does that mean a laboratory has to change the number on its reference weight's certificate?



Herman

Potentially, as updated values propagate through calibrations. It does not mean someone files metal off every weight. Usually you assign a corrected mass value and its uncertainty. A standard labelled one kilogram need not have an assigned value of exactly one kilogram.



Corn

The engraving is allowed to be less informed than the paperwork.



Herman

Corn, does the consensus arrangement bother you? It sounds less clean than a constant.



Corn

Only if somebody pretends the uncertainty disappeared. Several independent experiments, openly compared, sound stronger than making the most photogenic machine the monarch.



Herman

The coordination has actual people responsible for it, too. Annette Koo became BIPM director in January, succeeding Martin Milton, who led it through the redefinition. Behind those institutional initials are operators, technicians and comparison organisers maintaining continuity across leadership changes.



Corn

Well, that is the mass metrology sorted. Dorothy, you are on the line. What is cooking?

D

Dorothy

Hello dear, it is your mother. I am doing Dorothy's Kitchen today.



Herman

Hello, Mum. I'm ready.

D

Dorothy

The recipe is a cup of hot water. The ingredients are water, and a cup. That is all. Do not get creative.

D

Dorothy

You fill the kettle, and then you watch it. You watch it the whole time, sweetheart, because the moment you turn your back it either sulks or it boils over. The bread is the same. Everything is the same.

D

Dorothy

Then the water goes in the cup, slowly, and you wait. The waiting is the important part. Things have gone wrong before with the waiting and I would rather not say how.



Corn

We're listening, Mum.

D

Dorothy

And do not use the butter. I do not trust the butter this week.

D

Dorothy

Anyway. Wear a cardigan, it is cold. Ring me when you get home.



Daniel

Going back to continuity, what physically survives from the old arrangement? Are the vault and weights still working infrastructure?



Corn

The former prototype survives at the BIPM. About thirty-nine millimetres across and equally tall, platinum alloyed with iridium. The famous storage arrangement involved three bell jars and a triple-locked basement vault, with different key holders. But its present role matters more than the old ceremony.



Herman

It no longer defines the kilogram. Comparisons had revealed divergence among the prototype and its copies, and an artefact couldn't tell you which object had changed. The metal remains useful. In the BIPM's latest annual figures, it calibrated five platinum-iridium prototypes and eighteen stainless steel standards for thirteen national institutes.



Corn

Retirement has involved quite a lot of appointments.



Daniel

What makes those objects suitable? Why that metal, that shape, that handling?



Herman

Stability and characterisation. You want material that resists corrosion, a surface you can handle and clean reproducibly, and geometry suitable for precision comparisons. Platinum-iridium is very dense, so the object displaces relatively little air. Stainless steel is practical for many transfer and working standards.



Corn

Handling is part of the measurement. You don't put your reference kilogram beside the sink and assume it remains the same because nobody dropped it. Surface contamination changes mass. Cleaning can change mass too. The laboratory needs a defined procedure rather than a generally tidy person.



Herman

Temperature equilibration matters as well. Move a weight between environments and you may have to wait before comparing it. Air movement, buoyancy and thermal effects can interfere. The object is simple. The conditions around it are carefully managed.



Daniel

Is that why the primary balance works in vacuum? What happens when its kilogram has to return to ordinary air?



Herman

You explicitly bridge those environments. NIST describes weighing a kilogram in the Kibble balance in vacuum, comparing it with another mass, then transferring a mass into air. That becomes part of the chain used to calibrate a highly accurate balance, which calibrates further masses.



Corn

The transfer into air requires corrections. Otherwise you would quietly include the air's contribution in a measurement supposed to establish the object's mass.



Herman

A certificate records the assigned result, uncertainty and relevant conditions. Traceability belongs to that documented measurement chain. A shiny weight without those records is simply a shiny weight.



Daniel

The other units must look very different physically. Is there any equivalent of a reference object for time now?



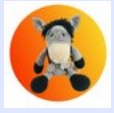
Herman

A primary second can come from a cesium fountain. Roughly a hundred thousand atoms are laser-cooled in a vacuum chamber and launched vertically. Microwaves interrogate their atomic transition during the flight, providing a frequency reference.



Corn

A clock that throws its contents upwards.



Herman

Very gently. NIST-F4's high-density performance has a fractional frequency instability around one and a half parts in ten trillion at one second of averaging. Longer averaging improves that statistical stability. That's stability, though... not a complete statement of its accuracy.



Daniel

I wouldn't have pictured a clock as a chamber containing a moving cloud.



Herman

Nor the metre as a beam of light, but optical frequency and interferometry make length measurements practical. For voltage, Josephson devices provide quantised electrical references. The laboratory still has racks, cables, temperature controls and people checking connections. The constant doesn't eliminate the apparatus.



Herman

Corn, where would you expect the longest delay between a primary result and something useful at a shop?



Corn

In the scheduling. Not light travelling or numbers being calculated. Someone needs a standard returned, a comparison completed, a certificate issued and an inspector available. You can have excellent physics and a queue.



Herman

That's a good reason for several levels of standards. The national laboratory cannot personally visit every checkout. State and local laboratories maintain working standards, and field standards travel to businesses.



Daniel

Walk me through the last part. The inspector arrives at a grocery shop. What actually comes out of the vehicle?



Corn

Weights. Durable field standards, not the platinum cylinder. In the American example, common increments are one, two and five pounds. Enough combinations let the inspector test different loads and approach the scale's full capacity.



Herman

Often thirty pounds for a grocery scale. You test how it behaves over its operating range, not merely whether it displays zero with an empty pan. Those field weights periodically return for comparison against working standards at the state or local laboratory.



Daniel

Does that local laboratory send everything back to NIST?



Herman

Its reference standards connect to NIST through calibration. Its working standards are compared against those references, and the travelling field standards against the working set. Different objects serve different roles so the best references don't suffer constant transport and handling.



Corn

The reference weight avoids the van. Sensible career choice.



Herman

Each comparison contributes uncertainty. You need the total uncertainty small enough for the job at the end. A longer chain can still be perfectly adequate if every link is understood and controlled.



Daniel

When I see the inspection sticker, what exactly am I being promised?



Corn

That the instrument passed the relevant inspection, under the applicable requirements, at that time. Not that every future reading is exact. Commercial scales are typically checked when introduced and periodically afterwards, with the date visible on the approval seal.



Herman

The scale can drift or be damaged between inspections. Periodic checks address that continuing risk. NIST estimates that roughly half of American economic activity depends on weights and measures. Small tolerances carry considerable commercial weight.



Corn

Truffles make the point expensively. At a thousand dollars a pound, an error of one hundredth of a pound costs ten dollars.



Daniel

How does the torque wrench fit? It's applying a turning force rather than weighing anything.



Herman

Torque connects force and distance. A calibration system applies known torque and compares the wrench's indicated or delivered response. Its standards require traceability for the relevant quantities, including the force and length measurements involved.



Corn

You don't put the wrench on the kilogram balance and congratulate it.



Herman

Laboratories such as Oak Ridge's Metrology Laboratory calibrate and adjust torque wrenches and transducers through documented comparisons back to national institutes. ISO IEC seventeen thousand and twenty-five sets requirements for competent testing and calibration laboratories. The certificate still has to describe the actual result.



Daniel

Calibration and adjustment aren't interchangeable, then?



Herman

Calibration establishes the relationship between the instrument and a reference, with uncertainty. Adjustment changes the instrument. You can calibrate a wrench, discover that it's outside tolerance and then adjust it. After adjustment, you need to establish how it now performs.



Hilbert

Salter bathroom scale, thirty-two pounds.



Hilbert

I'm doing the floor in my bathroom this month. Not laying it. Numbering it. Every tile gets a morning weighing and an evening weighing. I move the scale between them. There are forty-eight tiles and the floor plan is on my chest. I'm having it tattooed in stages because loose paper introduces movement.



Corn

The grout lines will make revisions awkward.



Hilbert

I allow a pencil correction on the skin until Friday. Then it becomes permanent. The scale says I weigh more beside the bath. I'm not interested in the Planck constant, Herman. I want to know where I'm lightest while still being able to reach the towel. Your explanation of the two balance modes is very clear, but mine only has the one mode and a button for stones.



Herman

Different support conditions could change a bathroom scale's reading. You're comparing the entire placement, not just yourself.



Hilbert

That's the fascinating part. Same body. Same scale. A different tile gives a different answer. I'm taking the readings in the same dressing gown. The manufacturer says hard level floor. It doesn't identify a tile. That leaves forty-eight possible places to comply, which I consider unfinished instructions. I spend twenty-two minutes each morning moving it. The evening takes longer because the bathmat is wet.



Corn

Your lightest position could disappear when you replace the floor. The map would describe a bathroom you no longer have.



Herman

Even changing how the scale's feet sit across a grout line could matter. The tattoo would need the orientation as well as the tile.



Hilbert

Orientation goes beside the ribs. The replacement floor is a fair objection. I'll leave that shoulder blank.



Daniel

That makes the certificate's conditions sound much less like administrative detail. Even a valid measurement can be applied somewhere it doesn't belong.



Herman

Conditions delimit the result. A laboratory can't promise the same performance after transport, damage or a different setup without checking. Traceability and fitness for purpose have to meet at the instrument people actually use.



Corn

What changed for me is how much of this system exists to preserve a measurement while moving it. The constant stays put. The weights, environments and people don't.



Herman

More independent realisations could shorten some transfers, while comparisons would still be needed to show that those local machines agree.



Daniel

Could that realistically reach an ordinary mass laboratory?



Herman

NIST delivered a prototype tabletop Kibble balance to the US Army in twenty twenty-four. If those become practical across mass laboratories, the interesting future is a network of checked realisations, with less time spent waiting for travelling standards.



Corn

Thanks to Hilbert Flumingtop for producing today's episode.



Herman

If you want more of this, try episode three, Safetensors or something else; episode fifty-eight eighty-six, From Leviticus to the Kilogram; and episode twenty, Architectural AI. This has been My Weird Prompts, the human-AI collaboration podcast.



Corn

If you enjoy the show, leave us a review wherever you listen.



Daniel

Thanks for listening.



Herman

See you tomorrow.

SOURCES

What the research for this episode read before the script was written. Primary sources first.

1. **BIPM Annual Review 2025 (pp. 2 [primary]**
   4 read).
   https://www.bipm.org/documents/20126/294843953/Annual_Review_2025/f1f619b7-59c1-d676-f302-39e3b903e88f

2. **BIPM, International Prototype of the Kilogram page. [primary]**
   https://www.bipm.org/en/mass-metrology/ipk

3. **BIPM, *Mise en pratique* for the kilogram, Appendix 2 of the SI Brochure. [primary]**
https://www.bipm.org/documents/20126/41489673/SI-App2-kilogram.pdf

4. **NIST, NIST's Kibble balance: A Mass revolution, released 2025-06-02. [primary]**
https://www.nist.gov/news-events/news/2025/06/nists-kibble-balance-mass-revolution

5. **NIST, Measurement Standards, created 2022-04-28, updated 2022-05-23. [primary]**
https://www.nist.gov/feature-stories/why-you-need-standards/measurement-standards

6. **NIST, How Do You Know If Grocery Store Scales Are Accurate?, created 2025-02-24, updated 2025-04-03. [primary]**
https://www.nist.gov/how-do-you-measure-it/how-do-you-know-if-grocery-store-scales-are-accurate

7. **NIST Handbook 155, *Weights and Measures Program Requirements*, 2017 ed. [primary]**
https://nvlpubs.nist.gov/nistpubs/hb/2017/NIST.HB.155-2017.pdf

8. **NIST, Fountains of Atoms: Exquisite Timekeepers. [primary]**
https://www.nist.gov/atomic-clocks/how-atomic-clocks-work/fountains-atoms-exquisite-timekeepers

9. **Wikipedia, 2019 revision of the SI, last edited 2026-09-23.**
https://en.wikipedia.org/wiki/2019_revision_of_the_SI

10. **Wikipedia, International Bureau of Weights and Measures, last edited 2026-10-24.**
https://en.wikipedia.org/wiki/International_Bureau_of_Weights_and_Measures

11. **Wikipedia, International System of Units, last edited 2026-10-22.**
https://en.wikipedia.org/wiki/International_System_of_Units

12. ***Metrologia*, Accuracy evaluation of primary frequency standard NIST-F4, 2025.**
https://doi.org/10.1088/1681-7575/adc7bd

13. **Physics World, Au revoir, kilogram.**
https://physicsworld.com/a/au-revoir-kilogram/

14. **Atlas Obscura, Le Grand K in Saint-Cloud.**
https://www.atlasobscura.com/places/le-grand-k/

15. ***Le Parisien*, 2025-09-06.**
https://www.leparisien.fr/sciences/kilogramme-metre-ou-seconde-plongee-dans-lintrigant-bunker-parisien-qui-protege-nos-unites-de-mesure-06-09-2025-3FG6YWDLFVCDXK7ZTHUAPNJ2S4.php

16. **ORNL Metrology Laboratory capabilities (torque calibration).**
https://metrology.ornl.gov/capabilities/