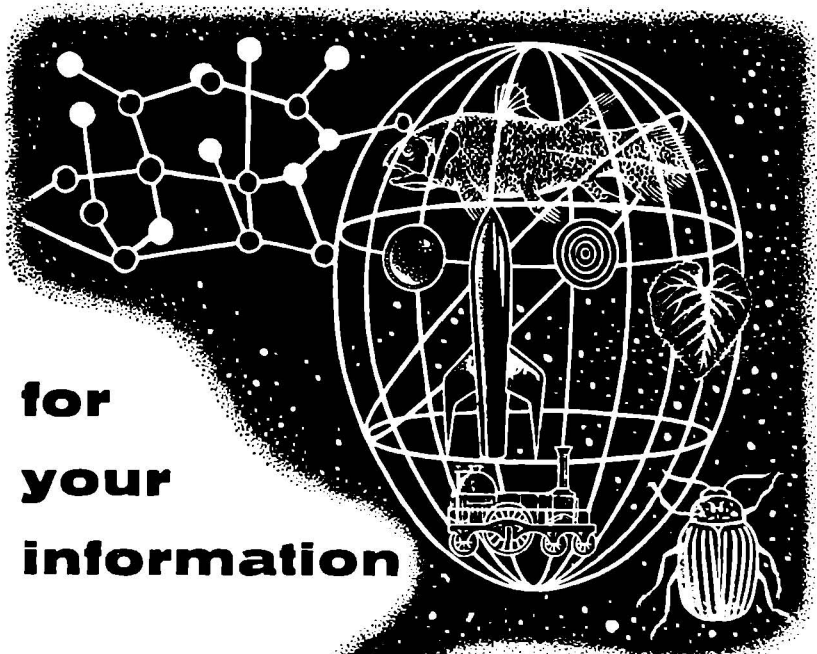


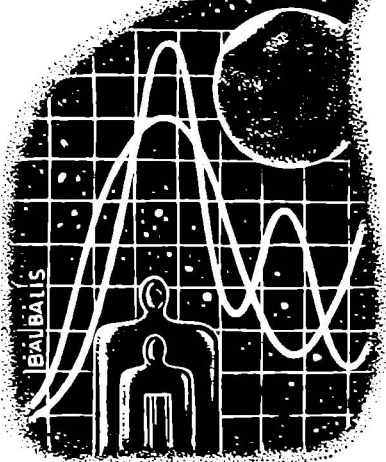
**for
your
information**



BY WILLY LEY

THE EARLY DAYS OF THE METRIC SYSTEM

It may be traditional to divide a length called a foot into twelve inches and then chop up these inches into halves, quarters, etc. Or, going the other way, to say that three feet make one yard (why not four, since the inch gets quartered?) and end



Comparison of the Pound Avoirdupois and the Foot with other "pounds" and "feet" in 1704.

	Pound	Foot
London	1.000	1.000
Paris	.930	1.068
Amsterdam	.930	.942
Leyden	.960	1.033
Antwerp	.980	.946
Strasbourg	.930	.920
Bremen	.940	.964
Cologne	.970	.954
Frankfurt on the Main	.930	.948
Toledo	1.000	.899

* According to the *Lexicon Technicum* by John Harris.

up with the interesting figure of 5280 feet to a mile.

It may be equally traditional to say that one shilling contains twelve pence and that twenty shillings make one pound. At least one historian holds that this relationship represents an original relationship of values, namely that one pound of gold was worth twenty pounds of silver while each pound of silver bought twelve pounds of copper.

While these things may be traditional they are also quite impractical. Every individual has had to memorize them at one time in his or her life. On the other hand, it needs no time at all to "memorize" that there are 100 cents in the dollar, or that 1000 millimeters make one meter, and 1000 meters make one kilometer. Since most of the household and workshop arith-

metic can be carried out in one's head when using the metric system, but needs paper and pencil when carried out in the inch-foot system, the statement that the metric system will win out eventually does not even deserve the label "prediction".

But how did it start and why?

The "why" begins with the fact that in, say, 1700 there was no system at all.

If this statement makes you think that each country had its own "pound", and "foot" and "mile" you are only partly right. In actual fact, it was not each country, but each province; and sometimes the northern part of a province used one set of measurements while the southern part of the province used another one. And the cities, being rich, were much too proud to use the rural measurements of the surrounding countryside, so they had their own.

The country that was best off in this chaos was England. There one system was used throughout by royal decree. But in France there was no such uniformity; in the northern part of the country alone the pound had twenty-one different values, depending on where you happened to be. As for measures for grain, not less than three hundred different kinds have been compiled by pa-

tient historians. Their relationships were sometimes simple, as when a city council might decree that the city unit for grain was three of the units of the surrounding countryside.

But sometimes the relationships were anything but simple. In fact they were sometimes so complicated that a mathematician had to be called in, as was the case in 1626 when the council of the City of Ulm called on the great Johannes Kepler to straighten out their measurements. The merchants could never agree on the length of a "shoe" and the question of how much grain constituted a "bucket" often had the result that the suppliers and customers flung actual buckets at each other. Kepler accepted the job for two reasons. One was that the mathematical aspects of the problem intrigued him. The other was that the city paid him.

The final outcome was the "Kettle of Ulm", a metal container which combined all the customary measurements. They were listed on the outside of the kettle in raised letters, even rhyming. The inside diameter of the kettle was one ell, its depth was two shoes, its capacity "one honest bucket". The weight of the kettle, when empty, was $4\frac{1}{2}$ units; when full of water it was 7 units. And now we come to the

problem of the grain measure: if you filled the kettle 64 times with grain you had 90 measures!

If one reads that in those days money changers and merchants coped with the endless varieties of silver and of gold coins by just weighing them it looks at first glance as if at least the money changers had found a useful shortcut, based on the fact that a pound of silver is a pound of silver, and a pound of gold is a pound of gold. Well, yes. But which pound? The pound of London, or that of Strasbourg (which was less), or that of Hamburg (which the English then called Hamborough and which was .95 of the London pound), or that of Leipzig, which was 1.15 of the London pound?

No wonder that, in 1704, the Englishman John Harris compiled a book called *Lexicon Technicum* which contained endless tables of how the pound of Calcutta, Rotterdam, etc. compared with that of England; other long tables compared the foot of the various countries. Glancing over these tables now, one sees with a good deal of astonishment that the "Spanish foot" was the same as the English, but the "Toledo foot" was shorter (see Table) while, on the other hand, the Toledo pound was the same as the English.

(There seems to have been no "Spanish pound.")

But the internal confusion was greatest in France. Many Frenchmen felt that, if the king of England could decree uniform measurements throughout his realm, the king of France should do the same. The French, at the time, had a system of making complaints and suggestions. The documents bore the name of *Cahiers de doléances* (writs of grievances) and they seem to have contained complaints about the lack of uniform measurements almost every year. The earliest known was in a *cahier* of 1576. By about 1785, the government in Paris decided that a reform should be considered. Reading about a two-century interval one is reminded of the famous lines—

the government,
the truth to tell,
did nothing in particular,
but did it very well!

But it was not just a case of indifference and procrastination. To say that things are confused and that a reform is needed is one thing. Making useful suggestions for a reform is something else. The French government—ultimately the king—seems to have felt that the suggestions were incomplete in

themselves. At any event that they were not definite enough to base decrees and laws on them.

The English had taken their measurements from the human body. The "foot" was an actual foot; that is, it was the average of the foot lengths of a dozen grown men, picked at random (or so the story goes). Now it so happened that 36 barleycorns "from the center of an ear" made one foot; therefore the "barleycorn" became the subdivision of an inch, with three barleycorn to the inch. Later on most artisans decided that halving and quartering the inch was easier, so only bootmakers continued to use the barleycorn as the smaller unit—a practice still continued by shoe manufacturers in England and in the United States. A difference of one size means a difference of one barleycorn, or one third of an inch, in length. It also happened that a piece of rope stretched from fingertip to fingertip across the chest of a man (a "fathom") was very closely six feet, and one half of that became a yard.

The official English measurements, then, were based on the human body, and the measures of other areas and cities probably were too. But the French scientists did not wish to follow

this pattern. The dimensions of the human body were too variable. Basing a set of official measures on the size of the planet Earth was more to their liking, since the size of the planet would not change. That was, of course, true enough; the problem was that the size of the planet was not accurately known.

It is not surprising that the first man to propose using the planet Earth as a standard was an astronomer. He was Jacques Cassini, and for that reason often called Cassini the Second. He suggested in 1720 that the standard foot should be the hundredth part of one second of arc of a meridian. The French Academy thought this a fine and logical suggestion, which only had the one drawback that the various attempts to measure the length of a meridian showed rather poor agreement. About thirty years later another French scientist, the mathematician and astronomer Charles-Marie de la Condamine, came with another suggestion which would be easier to carry out in practice.

Galileo Galilei had been the first to notice that the time required for a pendulum to complete one swing depended on the length of the pendulum. In reality the time required depends on two factors, namely the length of the pendulum and the lati-

tude, but Galileo did not know that. It was suspected by the astronomer Jean Picard that latitude might be a factor involved. But Picard made the general suggestion that a pendulum of a length resulting in a period of one second would be a useful basis for linear measurements.

The length of the seconds pendulum, it may be mentioned at this point, is 39.01 inches, or 99.09 centimeters; this is the standard figure, which requires a correction for the latitude.

To get away from the need for corrections, de la Condamine suggested the length of the seconds pendulum *at the equator* as the unit for linear measurement.

So these were the two suggestions, either a fraction of the length of the meridian, or else the length of the seconds pendulum. But both still had to be determined.

Along with the problem of finding a standard length which would not vary — and which could be re-established in case a catastrophe of some kind destroyed the first standard — there was the problem of subdivision of the standard. Thinking in dozens was customary; as we have seen the foot was divided into a dozen inches or into three dozen barleycorns. But

the dozen was not the only sub-unit or super-unit in use. In some places the foot was divided into eighths, and in Germany things like eggs or hard rolls were sold not by the dozen, but by the *Mandel* which was 15 units. To make things worse the Germans had the "peasant's mandel" in addition; it consisted of 16 units. (Remember the "baker's dozen".)

A dozen may be superior to ten because it can be divided by 2, 3, 4 and 6, while ten can only be divided by 2 and 5, but it so happens that we have ten fingers. A division into ten sub-units is therefore easier to visualize, at least for the beginner. The man who was the first to advocate subdivision into tenths was the Dutch mathematician Simon Stevin, military engineer to Count Maurits of Nassau. Stevin was not concerned with the measurements themselves or their origin and accuracy; he just advocated subdivision into decimal fractions. In order to find a larger audience he wrote his book twice, once in Latin and once in French. Both versions were printed in Leyden in 1585. The title of the French version was *La Disme*, and the English translation by Robert Norton (published in 1608) was called *Disme: The Art of Tenths, or, Decimall Arithmetick*.

The word *disme* means "tenth" and is related to "tithe". At one time it was the name of an American coin, the Half Dismes and Dismes between 1792 and 1800, later spelled "dimes".

Apparently Simon Stevin's book in its various editions convinced everyone — with the exception of the Master of the Royal Mint — of the superiority of decimal fractions, for the French Academy decided from the outset that this is what they would use in carrying out the mandate from the National Assembly to create a new system of weights and measures. The National Assembly had recommended the length of the seconds pendulum as a suitable (and repeatable) physical constant, but it had not said anything about decimal fractions.

But while the Academy decided on decimal fractions it also decided that the meridian would be superior to the seconds pendulum as a standard. It recommended in 1791 that the ten millionth part of the distance from the pole to the equator should be the new unit of measurement, the meter. The National Assembly accepted the recommendation. And then the hard work of measuring began.

In the meantime the savants had to fight with words. The unit was to be the meter (in French

metre) and a tenth of a meter was a decimeter. A tenth of a decimeter, or a hundredth of a meter, was obviously a centimeter. The tenth part of a centimeter was a millimeter—the word means a thousandth of a meter.

Going the other way, a term meaning a thousand meters was needed. The Greek word *chilioi* suggested itself, in spite of two drawbacks. In Greek letters the “ch” was the letter *chi*, which looks like an x. But the letter *chi*, considered as a numeral, meant 600. However, the Greeks themselves had often used the *chi* to mean 1000, as an abbreviation of the word *chilioi*.

One thing somewhat disturbing to Frenchmen was that all classical scholars were agreed that the *chi* was a guttural and Frenchmen, for no better reason that they cannot pronounce them easily, are opposed to gutturals. But somebody saved the day by discovering that the Ionian dialect of Greek used a *kappa* instead of the *chi*—the Ionians apparently were opposed to gutturals too—and the name of the unit of 1000 meters became the kilometer.

Now the unit of linear measure was to be the ten millionth part of the distance from a pole to the equator. This could

be determined without much difficulty from the figure provided by Nicolas-Louis de Lacaille, who derived the length of one degree of the meridian under 45 latitude as 57,027 *toises*, each *toise* being six feet Parisian. (Take it from there... if you have absolutely nothing else to do.) But the new system also was to include weights, and the unit of weight was to be the weight of a unit volume of distilled water weighed in a vacuum chamber at the temperature of melting ice. The name chosen for this unit was *gravet*.

Later on the unit volume was chosen as one cubic centimeter, and the temperature was shifted from that of melting ice to 4 degrees centigrade because at that temperature water shows its greatest density. Finally the name of this unit weight became *gram*, with kilogram for a thousand of these units and ton (metric ton) for a thousand kilograms.

Everything would have been fine if France had not become a republic in the meantime. Now the work of establishing the new system was under a new commission. Of course it had the name of *Commission temporaire des Poids & Mesures republicains*, the Temporary Commission for Republican Weights and Measures. The system that had been

meant for everybody in all countries had now become the "System of the Republic", just as they concocted a "Calendar of the Republic" which was finally abandoned by Napoleon to the jubilation of everybody. Whether the French revolutionaries actually intended the new system to be for France only is not quite clear, but the title page of the official book introducing the system sounded as if this were the case.

The title page read (the sign/ indicates that a new line began on the page): *Instruction/sur /Les Mesures/deduites/de la Grandeur de la Terre,/uniformes/Pour Toute la Republique/et/sur les calculs relatifs /a leur division decimale.* In English: Instructions on the Measurements derived from the size of the earth, uniform for the whole republic, with tables in decimal fractions.

With such a title page, the King of England, the King of Prussia, the Czar of all the Russians and every other king or prince could not only suspect that this might not be suitable for his country, he almost had to come to the conclusion that it should be forbidden in his country. As a matter of fact, because of these (purely accidental) political implications the new system made headway very slowly.

It made headway slowly in France too. The system became legal in December 1799 and the First Consul of the Republic Napoleon Bonaparte made it compulsory in 1801. But in 1837, several governments later, a law had to be passed imposing fines on recalcitrant silk and wine merchants (among others) who did not use the metric system exclusively beginning January 1, 1840.

By now the metric system is all but universal. The Russians adopted it in 1918, and in the two countries which are still holding out, the British Commonwealth and the United States, it is at least legal. In the United States, as a matter of fact, the yard and pound, etc., are defined in terms of the metric system, so that a housewife buying two yards of fabric is actually buying according to the metric system, though she is not likely to know the fact unless her husband happens to be a lawyer or a scientist.

What opposition to the metric system remains is usually based on invested capital. A factory will say that it has X million dollars invested in non-metric machinery, and even though these machines could be converted it would not do any good, because the raw material, bar stock, etc., comes in non-metric

dimensions from the rolling mill. And the rolling mill says, of course, that they have X million dollars invested in *their* machinery.

It is an opposition which will slowly dwindle away. But as far as argumentation is concerned it is certainly superior to that of a now forgotten society which existed in 1879 (and for a few years after) in Boston.

The background for this society had been the attempt of Charles Piazzzi Smyth, Astronomer Royal for Scotland, to find all kinds of "cosmic secrets" in the Great Pyramid. Assuming that the number of the days of the year had to be hidden in the base line of the Great Pyramid, Piazzzi Smyth divided the base line into 365.2422 parts and named the unit thus derived the "pyramid meter". This he then divided into 25 parts to obtain the "pyramid inch", which turn-

ed out to be almost the same as the English inch.

Piazzzi Smyth quickly concluded that the English inch was just a faintly corrupted "pyramid inch". Hence the English system of measurement by inches really went back to ancient Egypt. By 1870 most of those who played around with the dimensions of the Great Pyramid had also concluded that the pyramid had been divinely inspired in the most literal meaning of the term. Hence the inch was sacred. Hence it was necessary to form a society with the ultimate purpose of outlawing the "atheist metric system". James Abram Garfield, later president of the United States, was an active supporter of this movement against the meter.

The movement did not last long.

Besides, the metric system had been legalized in 1866.

Any Questions?

What are the "lost Messier objects?"

George P. Wallace
Boston, Mass.

In 1771 the French astronomer Charles Messier published the first version of his *Catalogue*

of *Nebulosities*, which was a by-product of Messier's main work — namely the hunting for new comets. Since a comet, before it develops a tail, looks like a fuzzy star, and since Messier knew that there are some objects in the sky which always look that

way, it was only natural that he compile a catalogue of these objects so that he would not waste observing time on them.

The objects listed in Messier's catalogue are now referred to with numbers preceded by an M. M-1 for example, is the crab nebula, M-13 the globular cluster in Hercules, M-31 the "nebula" (galaxy) in Andromeda. Two objects, namely M-40 and M-91, could not be found by later astronomers and are therefore called the "lost Messier objects". It is believed that they were faint comets which Messier mistook for permanent nebulous objects.

The announcement of the discovery of a third extra-solar planet by Dr. Peter van de Camp prompts me to ask whether there is any chance of actually seeing or at least photographing such planets. I understand that the new extra-solar planet is a dark companion of Barnard's Star, which is itself quite faint, and that its presence was deduced from the examination of minute changes of position of the visible star. While I don't doubt its existence, I think it would be a reason for rejoicing if the deduction could be verified photographically.

J. D. Carbonara
Phoenix, Arizona.

I agree that it would be "reason for rejoicing" if any one of the three extra-solar planets now on record (the earlier two are those of 61 Cygni and of Lalande 2185) could be verified photographically. I could even cite historical precedent. It was Friedrich Wilhelm Bessel who was the first to deduce the existence of a body in space in this manner. He deduced the existence of a Companion of Sirius, and later of a Companion of Procyon, and both were discovered visually at a later date when telescopes had grown larger. But in both cases the companions were dwarf stars—bodies of stellar mass but of planetary dimensions. They are self-luminous.

The three extra-solar planets now known are of planetary mass and planetary dimensions, though quite large. The two bodies accompanying 61 Cygni and Lalande 2185 must have a mass of about one per cent of the mass of our sun, while the "planet" of Barnard's Star has only about one and a half times the mass of the planet Jupiter. It would be most surprising (though not completely impossible) if they were self-luminous.

The question of whether a true planet, visible by reflected light only, could be observed (or just seen) over a distance of several

light-years has been investigated by several astronomers, e. g., the late Dr. Otto Struve and Dr. Lyman Spitzer. Dr. Spitzer assumed a planet of the same albedo as Jupiter, orbiting its star at the same distance as Jupiter orbits our sun. If that planetary system were 16 light-years distant the maximum separation of star and planet would be one second of arc.

It is easy to make the case seem hopeless by saying that a separation of one second of arc is equal to the diameter of a quarter-dollar coin seen from a distance of three miles. This is quite true, but it is also true that it does not need a very large telescope to see two luminous points which are separated by one second of arc. The crux of the matter is that both points should be of about the same luminosity for easy separation, and a sun and its planet differ enormously in luminosity. If we imagine astronomers 16 light-years away looking for Jupiter, they would find that the sun is approximately 900 million times as luminous as the planet. It is like somebody waving a flashlight next to a battery of searchlights. And if the astronomers of that other planet have to look through an atmosphere the case becomes hopeless.

They could improve their lot by placing their telescope on an atmosphereless satellite and by using an occulting disk which cuts off as much of the light of the star as possible, but will permit most of the light of the planet to pass when it is in a favorable position. Even then they would need a 300-inch telescope. Our time for rejoicing, therefore, won't come until we have a lunar observatory with more powerful instruments than we have on earth right now.

Looking through several Almanacs, I notice that the number of isotopes for the various elements differs from list to list. This, I presume, is the result of new discoveries. The almanacs are for different years. What I would like to know is whether there are elements which have only one isotope.

Herman Howard
Manhattan, Kansas.

If we disregard radioactive isotopes, natural or artificial, there are eighteen elements which have only one *stable* isotope. In alphabetical order they are: Aluminum, Arsenic, Beryllium, Caesium, Cobalt, Fluorine, Gold, Holmium, Iodine, Manganese, Phosphorus, Praseodymium, Rhodium, Scandium, Sodium, Terbium, Thulium and Yttrium.

The element with the largest number of stable isotopes is Tin which has ten, followed by Cadmium which has eight. The other elements have two or more, but less than eight, stable isotopes. The total number of stable isotopes now known is around 280.

Would you please write a piece on the names of the artificial satellites. What do their names mean?

Marion McNamara
Salem, Ohio

Let me begin with the Russian satellites because there are fewer of them. The first Russian satellite was named *Sputnik*, which is a Russian word compounded from "s" (meaning "with"), "put" (pronounced poot, meaning "road") and the suffix "nik" which makes the word a noun. It therefore means "travel companion". Incidentally, the Russian plural is *sputniki*.

The manned capsules are named *Vostok*, which is the Russian word for "East", but the name has historical significance. The first Russian sailing ship which circumnavigated the globe happened to be called *Vostok*. The current series of Russian research satellites is called *Cosmos*; no explanation necessary. The term "Lunik" is an invention of American news-

papermen, not a Russian word or designation. The first Russian planetary probe was the only one which had a name. It was called *Metchta*, which can best be translated as "daydream". Since then the Russians have become very matter of fact. Their Mars probe which is now in space is just called "Mars,1".

Our first satellite was named *Explorer* and our first to be fired over the poles was named *Discoverer*, and it has become customary to name satellites in polar orbits Discoverers while the ones in orbits more or less over the equator are named Explorers.

The moon rockets were named Pioneer, and later Ranger while the planetary probes are called Mariner, all three obvious names. But some other names are less obvious. The satellite ANNA has that name because it was a joint project of Army, Navy, NASA and Air Force. The satellite OSO indicated its purpose: Orbiting Solar Observatory. One that is coming up will be named POGO, from Polar Orbiting Geophysical Observatory. As for *Transit*, the name is clear once you know that it is a navigational satellite. The Canadian satellite (fired by a U. S. rocket from Cape Canaveral) is named *Alouette*, which is French for "Skylark".

The satellite *Syncom* is somewhat more complicated. It means a communications satellite in the synchronous orbit, 22,300 miles above the equator, needing 24 hours to go around the earth once and therefore seemingly hanging motionless over one point of the equator. *Midas* stands for Missile Defense Alarm System and *Samos* for Satellite and Missile Observation System. *Echo* was called that because the inflated balloon produced an echo of radio waves thrown at it, while the weather satellites *Tiros* are Television and Infra-red Observation Satellites. The little satellite *Oscar*, for the use of radio "hams", had this name from the initials of Orbital Satellite Carrying Amateur Radio.

Clumsiest name ever was that of Project SCORE back in December, 1958. Its name stood for Satellite Communications by Orbiting Relay Equipment!

Our local newspaper recently printed a release from NASA in which the word "meteoroid" was used. What is a meteoroid? And since I am at it, why are the words "meteorite" and "meteorology" so similar, since they mean such different things?

Elmer Green
Trenton, New Jersey

The best way to answer this question is to proceed historically. The classical Greek word *meteoros* means lofty, or high, while the word *logos* means knowledge. Therefore, when Aristotle wrote a book on weather he called it *Meteorologica* — the knowledge of things which happen high up — and the science of weather and weather forecasting is still called "meteorology."

But Aristotle thought that certain phenomena, say shooting stars, were events in the atmosphere — which, of course, is correct as far as it goes. A shooting star is an event taking place in the atmosphere; that it was of astronomical origin was not known in the ancient world. Later stones that had fallen out of the sky were called meteors or meteorites. The two words were used interchangeably at first — they are still so used in several languages — but then English astronomical usage began to make a sharp distinction. A meteorite was the body that could be picked up from the ground, while the flash it made in the sky was the meteor. The term meteoroid is recent, and is meant to designate meteorites still in space, before they have entered the earth's atmosphere.

—WILLY LEY