Relativity Documentary Outline

Title (tentative): Einstein's Relativity Theory Overturned by Elementary Algebra

1) The documentary begins by recalling some of Einstein's past achievements. In 1905 he had three landmark publications which still have a great impact on physics. The subjects were Brownian motion, the photoelectric effect and the theory of relativity. He is best known by the general public for his work on relativity, the background for which is discussed in the following.

2) In the latter half of the 19th century experiments were reported that baffled the physics community. They appeared to show that there was something very unusual about the speed with which light travels through a vacuum. To see what this was it is helpful to consider a simple example from everyday experience. Imagine a train moving along at a speed of 60 mph relative to a stationary position on the ground. Then consider how the train's movement is perceived by a passenger in an automobile moving at a speed of 50 mph toward the train. To him it will appear that the train is only moving at 10 mph. If he speeds up to 70 mph it will actually look to him as though the train is moving backwards at 10 mph. This is a basic fact of nature that the speed of an object depends the state of motion of the observer. The above example illustrates that it is a very simple matter to predict what speed a given observer will measure for the train once the latter's speed relative to the ground is known.

3)The mathematical equations that describe the above relationships are traditionally referred to as the Galilean transformation. The above experiments were so surprising for physicists because they appeared to be completely inconsistent with the above equations. They showed instead that the speed of light moving through a vacuum does not depend in any way on the speed of the observer. One could even go back to an experiment (referred to as the Fresnel light-drag experiment) first carried out in 1810 to find support for this finding. There was at first a general belief that something must be wrong with these experiments, but work carried out by Michelson and Morley in 1887 with a new device known as an interferometer seemed to prove beyond a shadow of doubt that the speed of light in a vacuum has the same constant value (300000 km/s or 671 million mph) independent of the state of motion of the observer.

4)Scientists began a frantic search for an "ether" in which the light was permanently at rest, in analogy to the theory of sound waves. Along came a little-known scientist in Germany named Woldemar Voigt, however. He proposed in 1887 that the problem lay in the Galilean transformation itself. In particular, he suggested that the complete separation of time and space assumed in the above equations needed to be dispensed with. This was the first known example for what is known as "space-time mixing." This idea went against the teachings of Sir Isaac Newton that had been followed religiously for over 200 years at that point. On this basis Voigt was able to derive a new set of equations which was consistent with the light-speed constancy finding while at the same time without coming in conflict with the everyday experience with trains and cars mentioned above. His solution to the problem only involved simple algebra and did not have to assume an "ether" to obtain its results.

5)There was a glaring problem with the Voigt transformation, however. It did not subscribe to another of physicists' cherished beliefs: the Relativity Principle. The latter was introduced by Galileo in 1623 and had its basis with experiments he was carrying out with his newly invented telescope. He realized that the earth must be moving at a very high speed (30 km/s) to make the round trip around the sun in a year's time. It intrigued him to think that we don't notice that we are moving at such a fantastic speed. He compared the situation to what people would perceive when they were closed up in the hold of a boat. He concluded that they would be unable to distinguish between the case when their boat was still at the dock or had moved out to sail on a perfectly calm sea. Today, this conclusion is formulated in a tantalizingly simple way: The laws of physics are the same in every rest frame. A decade after Voigt's paper had appeared, both Joseph Larmor and Hendrik Antoon Lorentz came up with a closely related transformation. It differed from Voigt's in that his equations were modified by introducing the same constant multiplying each of its right-hand sides. This change did not affect either the space-time assumption or the light-speed constancy in Voigt's transformation, but it did make the result perfectly compatible with the Relativity Principle. The concept of an ether persisted, however. These four equations have become very famous and are referred to together as the "Lorentz transformation."

6) Einstein's 1905 paper on relativity did not mention the previous work that had led to the Lorentz transformation. Instead, he went on to derive it from scratch. He did this by making two "postulates" on which to base his derivation, namely the same light-speed constancy condition that Voigt had introduced while the other was the Relativity Principle. He made clear from the outset that he rejected any need for an ether to construct his theory. Along the way, he made another assumption without actually declaring it as such, however. He introduced another free parameter which he referred to as φ. It was exactly the same as the one Lorentz had used in his derivation but had called it ε instead. Einstein just described it as "a quantity which remains to be defined" and then went on to do so by simply stating that it could only be a function of the constant speed v by which the two rest frames (such as the car and the road on which it travels in the example at the outset) connected by the transformation are separating from one another. That "hidden postulate" is sufficient to lead to a value of unity (φ=1 and/or ε=1), which in turn leads directly to the Lorentz transformation.

7)Einstein then went on to discuss a few predictions that follow directly from the Lorentz transformation. One of these is referred to as "remote non-simultaneity." It maintains that two events which occur at the same time (such as lightning strikes) for an observer in one rest frame may not occur simultaneously for someone in a different rest frame. This conclusion was very much at odds with what classical physicists had believed since Newton's time. It is clearly tied up with the space-time mixing characteristic of the LT and also that of Voigt's earlier transformation. The non-simultaneity possibility had earlier been discussed by Henri Poincaré. He had simply concluded that no experiment carried out to that time could be claimed to exclude it from the realm of possibility. Einstein predicted something else that shocked his contemporaries, however. He concluded that clocks in relative motion must run at different rates. The ratio X of the two rates could only be function of the relative speed of the two clocks. This predicted phenomenon is now referred to as "time dilation." He went further to conclude that each observer traveling with the clocks would find that it was the other's which was running slower. This was shocking for both physicists and philosophers alike since it indicated that the results of physical measurements are simply a matter of perspective. Some philosophers seized on Einstein's conclusion as evidence that there was no such thing as an "absolute" in logical discussions.

8) The question that needs to be asked about Einstein's relativity theory is whether it is true that remote non-simultaneity and proportional time dilation actually occur in nature. The answer is surprising. It is in fact impossible for both effects to be true for the same application. Consider, for example, two lightning strikes. An observer in one rest frame finds that there is a time difference of Δt seconds. Because of time dilation it must be assumed that the corresponding time difference $\Delta t'$ for another observer in a different rest frame can be obtained by multiplying Δt with a fixed ratio X, i.e. $\Delta t' = X \Delta t$. According to the theory, this proportional relationship must hold true for all comparisons of elapsed times for a given pair

of events. Now suppose that the lightning strikes occur simultaneously for the first observer, i.e. the time difference for him is $\Delta t = 0$. Therefore, the second observer must also find the time difference using his clock has the same value of zero, i.e. $\Delta t' = X \Delta t = 0$. This result obviously contradicts the theoretical prediction of remote non-simultaneity, however, which claims that the lightning strikes that occur simultaneously for one observer will occur at different times for the other. In other words, *proportional time dilation is the antithesis of remote non-simultaneity.* Both effects cannot occur for the same pair of events for the simple reason that multiplying zero with any (finite) number must produce a result of zero. This is a fundamental relation of algebra that cannot be violated in any physical theory. Either the clock rates in the two rest frames are not strictly proportional to one another, thereby contradicting the prediction of time dilation, or one has to accept the fact that what is simultaneous for one observer is also simultaneous for the other, thereby contradicting the remote non-simultaneity prediction of the same theory. *This state of affairs therefore leads to an unavoidable logical conclusion, namely that the Lorentz transformation, on which both effects rely, is not a valid theory.*

9) So, where did Einstein make his mistake? The most obvious answer is because of his decision to rely on the "hidden postulate" mentioned above (see point #6). He had no reason to assume that the constant φ could only depend on the relative speed v of the two rest frames. In retrospect, his justification was merely *ad hoc*. It allowed him to get his desired result of $\varphi = 1$ and thereby satisfy the Relativity Principle in a straightforward way. He also took it for granted that the space-time mixing character of the resulting transformation was consistent with all observations. He did not understand that this (Lorentz) transformation is clearly invalid because of the incompatibility of its two predictions of remote non-simultaneity and proportional time dilation.

10) What should Einstein have done differently to avoid the mistakes of the Lorentz transformation? The simple answer is that he should have thought more carefully about Newton's views on the general subject of space and time. He should not have opted for the concept of space-time mixing, something that he knew full-well was abhorrent to Newton and classical physicists in general. To see that there was, and still is, a ready alternative, all one has to do is to realize that the clocks referred to in the descriptions of proportional time dilation and remote non-simultaneity are assumed to be "inertial systems," that is, they are considered to be moving under the complete absence of external forces. Einstein certainly understood that, in accordance with Newton's First Law, this meant that all such clocks must move with both constant speed and direction for an indefinite period of time. But what about their rates? Since there is no unbalanced external force acting on the clocks, the obvious deduction is that their rates, like their speed and direction, should also be constant. The rates of any two such inertial clocks would not necessarily be the same, however, but the assumption that each of them is constant *implies that their ratio would be constant as well.* One can also say that the Law of Causality demands this. The elapsed time measured by them for the same event therefore must satisfy the proportionality relation: $\Delta t' = \Delta t/Q$, where Q is simply a proportional factor of unknown value. On this basis, Einstein could have proceeded in like manner as he did in his paper and used the above relation to define the value of the parameter φ in his derivation. When this is done, the result is no longer unity but rather a function of both the relative speed v of the two rest frames but also of the speed u of the object of the measurement. It is then a simple matter to use this value of φ to define a different space-time transformation, one which has become known as the Global Positioning System-Lorentz Transformation, or GPS-LT for short.

11) The above proportionality between elapsed times is one of the four equations of the GPS-LT. As such, it is clear that the new transformation does away with space-time mixing entirely and espouses instead Newton's belief in the complete separation of space and time. One is measured with a meter stick and the other with a clock, exactly as one knows from everyday measurements. It is obvious from the $\Delta t' = \Delta t/Q$ relation that the new theory also predicts something akin to Einstein's time dilation. There is a clear difference in the two versions, however. The GPS-LT leaves no doubt which of two clocks runs slower. This is determined uniquely by knowing whether the constant Q is greater or less than unity ($Q>1$ or $Q<1$). The measurement of time is thereby assumed to be completely *objective* in this theory of relativity. This is in total contrast to the case in Einstein's theory, according to which one must assume that it is *purely a matter of perspective* which of the two clocks runs slower. As mentioned above, this is clearly a *subjective* view of the measurement process in general, one which has long since become dogma for the physics community. The above proportionality between elapsed times in the GPS-LT equation does something else, however. It clearly removes any possibility of remote non-simultaneity: if $\Delta t=0$, there can be no question that $\Delta t' = 0$ as well, i.e. if the events are simultaneous for one observer, they also must be so for the other. This is the consequence of the simple rule of algebra that multiplication of any (finite) number by zero has a unique result of zero. If the events do not occur simultaneously for one observer, they also do not occur at the same time for the other, even though the two may well disagree about the value of the time difference is this case. The ratio of the difference is again uniquely determine by the constant Q in the GPS-LT.

12) The question naturally arises once one realizes that the Lorentz transformation is hopelessly flawed as to how it could nonetheless be possible for physicists to believe that it completely agreed with all relevant experimental findings. There are several reasons for this misconception. First of all, it needs to be pointed out that a number of the most important successes of Einstein's theory are only due *indirectly* to the Lorentz transformation. Instead, they are the direct consequence of the *relativistic velocity transformation*. For example, the key example of the aberration of light at the zenith, which is of critical importance in astronomy, can be derived without reference to the Lorentz transformation at all. The same is true of the explanation for the Fresnel light-drag phenomenon in moving liquids first pointed out in 1907 by Max von Laue. In addition, all the findings indicating that the speed of light in free space is the same for all observers can also be explained exclusively on the basis of the velocity transformation. The latter can be derived from the Lorentz transformation using a very simple procedure, namely to divide each of its spatial variables by the corresponding expression for elapsed time. *The same procedure when applied to the GPS-LT, however, leads to exactly the same velocity transformation.* Indeed, when the procedure is applied to Voigt's original space-time transformation, the result is again the same. The velocity transformation in fact results from any Lorentz-type transformation regardless of the value chosen for the φ parameter. That was the whole point of Lorentz's observation about such transformations in general as depending on what amounts to a free parameter in the theory. In summary, as important as the above predictions/explanations for the existence of key phenomena in nature certainly are, it cannot be claimed that the Lorentz transformation is in any way essential for such theoretical advances.

13) As a result, in order to truly differentiate between the characteristics of the GPS-LT and the Lorentz transformation, it is necessary to consider experiments in which either elapsed times or distances travelled are obtained directly in the experiments. This is the case for a number of investigations, some of which were reported as early as 1940. Decaying particles such as muons are a type of clock and so studying their lifetimes while moving at tremendously high speeds in the upper atmosphere allowed scientists to carry out meaningful

tests of Einstein's time-dilation prediction. He had also predicted a "transverse" Doppler effect for accelerated light sources. One found, for example, in experiments carried out by Ives and Stilwell that the frequency of light from a standard source is measurably smaller when the device undergoes acceleration in the laboratory. The observed frequency in the laboratory, after correcting for the conventional Doppler effect for motion toward a photographic plate, was smaller by a factor of $\gamma = (1-v^2c^{-2})^{-0.5}$ than the standard value (v is the speed of the light source and c = 299792458 m/s is the speed of light in a vacuum), in satisfactory agreement with Einstein's prediction. The lifetimes of the accelerated muons were also found to increase by this fractional amount. These results are in nearly quantitative agreement with his theory and were taken as strong evidence for the validity of the Lorentz transformation.

14) Nonetheless, the question remained open as to whether time dilation is symmetric or not, i.e. whether each observer finds that it is the other's clock that runs slower. Both the above experiments were seen from the standpoint of the laboratory observer. What would happen in the Ives-Stilwell experiment if the observer were moving along with the accelerated light source and he could measure the frequency from the same standard light source emitting radiation from the laboratory? In 1960 Hay et al. found a way to simulate such a two-way experiment by mounting a light source on a high-speed rotor. They showed that if an x-ray source was located at the axis of the rotor while the corresponding detector was mounted at the rim, a *higher frequency* than the standard value was indeed observed. This was certainly not in agreement with expectations from Einstein's theory. In other words, the effect was asymmetric; the "clock" at the outer rim was definitely slower that its counterpart (the x-ray source) at the axis. Note that this result is in agreement with the objective theory of time dilation implied by the $\Delta t' = \Delta t/Q$ equation of the GPS-LT, which clearly predicts that the measurement of elapsed times is not a matter of the perspective of the observer. The Hay et al. experiment was the first to contradict Einstein's predictions based on the Lorentz transformation. Physicists were not convinced that this was the case, however, and came up with what amounts to an *ad hoc* rationalization of the observed phenomena. They said the reason the theory had not made a correct prediction was because the x-ray detector was undergoing a high degree of acceleration in the experiment, whereas the Lorentz transformation could only be applied for freely translating (inertial) systems. It has been lost in the conversation that Einstein's theory was nevertheless contradicted by these results.

15) The invention of the atomic clock in the late 1960s allowed for a different test of time dilation which did not involve highly accelerated objects. Hafele and Keating took a number of these clocks on circumnavigating airplanes in 1971 to see if they would lose time in flight. This experiment was advertized as a test of the "clock paradox" suggested in Einstein's 1905 paper. According to his argument, a clock attached to an electron moving in a circular orbit would return to its starting point with less elapsed time than one left at rest behind there. Two airplanes were used in this experiment, flying in opposite directions around the earth. When they returned it was found that the eastward-flying clocks had less elapsed time than their counterparts left behind at the originating airport, whereas the westward-flying clocks had more elapsed time. The authors were able to explain these results quantitatively by assuming that at each point in the flight the rate of a given clock was inversely proportional to γ (v), where v is its speed v relative to the earth's center of mass (ECM). A correction for gravitational effects on the clock rates was required. This was calculated on the basis of the gravitational *red shift* formula introduced by Einstein in a 1907 paper. Perhaps the first thing to notice about these results is that the ratio of any two clock rates did not depend directly on their speed relative to each other, contrary to what one must expect from Einstein's version of

time dilation which is based on the Lorentz transformation. This is yet another indication that the LT is not correct.

16) The results of the Hafele-Keating circumnavigating airplane experiment are particularly important because they can be summarized in a marvelously simple way. They show that the elapsed time on a given clock, whether on an airplane or on the ground, is inversely proportional to γ (v), *where v is its speed relative to the ECM.* The relationship between the elapsed times of two clocks for the same event, one of which is travelling with speed v and the other with speed v', is therefore: $\Delta t \, \gamma (v) = \Delta t' \, \gamma (v')$. To apply this formula it is necessary to know that the speeds v and v' are measured with respect to a unique reference, in this case the ECM. What makes the formula even more significant is the observation that it also applies perfectly to rotor experiments carried out by Hay et al. All one has to realize is that the reference system in this case is the axis of the rotor. In general, one can reasonably assume that when two objects are accelerated relative to a given rest frame, their speeds must be measured relative to this rest frame in order to be applicable. It is therefore useful to have a general name of each such rest frame and this has led to the coining of the phrase: Objective Rest System (ORS). It is the ECM in the Hafele-Keating experiment, the rotor axis in the Hay-et al. study and the rest frame from which the objects are accelerated in the last case. Moreover, because of the general applicability of the above formula, it is useful to give it a specific name as well, specifically The Universal Time-Dilation Law (UTDL). As for any other law of nature, such as the Laws of Thermodynamics or Newton's Laws of Motion, it cannot be derived from so-called first principles. It simply summarizes in a wonderfully succinct manner all the results of timing measurements that have thus far been carried out experimentally. The hope is certainly that when an application is made to some other type of experiment which is fundamentally different than any of those that originally led to the law's formulation, the corresponding results will also fit in perfectly consistently with it. Moreover, it is expected that the law will suggest new experiments to test its applicability. For example, in the case of the UTDL, one can speculate that a clock will change its ORS from the ECM to the moon's center of mass when it moves out of the earth's gravity into that of the moon's. There are many other ways to test the UTDL, and one can hope that scientists will soon fix their attention on this goal much more decisively than has been the case thus far.

17) From a philosophical point of view the most significant aspect of the UTDL is its recognition that timing measurements are completely objective. There is no reason to expect that it might be impossible in principle to know which of two clocks is running slower at any given time. This objectivity characteristic allows one to do something that is impossible to accomplish in Einstein's version of relativity theory, namely to define a *unit of time* on which to base measured values. It makes no sense to attempt this if it not even clear which clock runs slower. What the UTDL tells us is that this unit changes when the standard clock, for example the period of an atomic line, is accelerated to a different rest frame. The quantity Q in the GPS-LT is seen as a *conversion factor* between the different units of time in the associated two rest frames. The reason observers in the two rest frames differ on the value of a given measurement is not because the object is not the same for both *but rather because they use a different unit of time on which to base their results.* The conversion factor Q allows anyone to predict the value one observer will report solely on the basis of what his counterpart in the other rest frame measures.

18) The question clearly arises as to whether the concept of units applies to other physical quantities. To show that it does, one only has to realize that the constancy of the light speed in free space implies that the unit of velocity is not affected in any way by acceleration. This fact in turn leads to a conclusion about the behavior of the unit of distance. If the theory is to

be completely objective, this means that the unit of distance must change in direct proportion to that of time. Only in that way can the unit of speed remain unchanged. Specifically, if the unit of time increases by a factor of Q>1 because the clock rate slows, the length of a standard measuring bar must increase by exactly the same factor. In other words, the bar increases in length and the increase must be the same in all directions. This means that *isotropic length expansion accompanies time dilation, i.e. the slowing down of clocks.* The conversion factors for time, distance and velocity are thus seen to be Q, Q and Q^0, respectively. At the same time, one knows from experiments carried out by Alfred Bucherer in 1909 that the inertial masses of accelerated electrons increase by exactly the same fraction as do the rates of standard clocks. In other words, the conversion factor for inertial mass is also Q. The corresponding factors for all other physical quantities can then be determined from their composition in terms of the standard units of distance, inertial mass, and time (meter, kilogram and second in the mks system of units). For example, angular momentum is a product of distance (Q), inertial mass (Q) and velocity (Q^0) and therefore its conversion factor is Q^2. The same factor holds for Planck's constant h because it has a unit of angular momentum. The conversion for frequency ν is Q^{-1} because it is the reciprocal of the period of radiation. Accordingly, one expects the energy E of a wave to vary as Q because it is the product of h and ν. The same result for energy results from consideration of its composition as inertial mass times the square of velocity. Einstein's famous $E=mc^2$ formula is also obviously consistent with this determination. It's even possible to compute conversion factors for all electromagnetic quantities.

19) A confusing aspect of the theory of units is that someone moving along with the standard objects can notice no change in their properties whatsoever. This is because of the fact that the dimensions of all co-moving objects change by exactly the same fraction. Both the object and the standard relative to which it is compared may have increased but since the result of any measurement is always a ratio, no difference can be perceived. In other words, there is a *uniform scaling* of all properties as a result of acceleration. This behavior is consistent with Galileo's Relativity Principle, which as mentioned above is one of Einstein's postulates of relativity used to derive the Lorentz Transformation. It is also an indispensible characteristic of the GPS-LT. On this basis, however, the Relativity Principle can be reasonably extended as follows: *The laws of physics are the same in every inertial system but the units on which they are based can and do change from one rest frame to another.*

20) The engineers who developed the Global Positioning System (GPS) for purposes of navigation used relativity theory in two distinct ways. The basic idea is to place a series of satellites in nearly circular orbits around the earth. By measuring the distance between each of a number of satellites and a definite position on the earth' surface, it is possible to pinpoint the location of the latter. The success of the technique therefore relies heavily on the ability to accurately measure these distances at any given time. This can be done in principle by sending a laser pulse between the known position of a given satellite and the corresponding position on the ground, and measuring the elapsed time ΔT for this to occur. Since one knows that there exists a nearly perfect vacuum in the space between these positions, it can safely be assumed that the speed of the light pulse is equal to c for all observers, in agreement with the second postulate of relativity. Consequently, the required distance can be obtained quite simply by multiplying c with ΔT. *The more difficult question to answer from a purely theoretical standpoint is how to accurately measure the time difference ΔT.* Because of the experience with circumnavigating clocks obtained by Hafele and Keating, one cannot simply assume that the rate of a clock at rest on the satellite is equal to that of the identical clock on the ground. The UTDL allows one to account for the rate difference by knowing what the respective speeds of the two clocks are relative to the ORS, which is the ECM in this case. A

correction also has to be made to account for the effect of gravity on the satellite clock, but the same experimental study demonstrated how this can be done accurately, namely by comparing the positions in the earth's gravitational field of each clock and computing the corresponding red shift on their rates. This is of course the second way in which relativity enters into the design of the GPS.

What is normally overlooked in this discussion is that according to Einstein's version of relativity, it is impossible to know which of the two clocks runs slower and therefore to come up with a unique value of ΔT that observers in both positions could agree upon. Moreover, it is not possible to assume according to the Lorentz transformation that an event such as the emission of a light pulse from the ground position occurs at the same time for both clocks. That conclusion runs counter to the remote non-simultaneity prediction of the LT. In other words, it makes no sense to compute the required time difference, even after appropriate adjustments have been made for the rates of the two clocks, when the satellite observer measures a different time of arrival than his counterpart on the ground. In essence, the GPS engineers completely ignored such theoretical objections and simply went ahead and decided a) that the clock on the satellite can be adjusted to run at exactly the same rate as that on the ground, and b) that the time of arrival on this clock would be exactly the same as measured on the ground clock. *The result would therefore be the same if it were possible to use the same clock for both measurements.* This procedure is perfectly consistent with the alternative version of relativity theory based on the GPS-LT. The fact that GPS works as well as it does on an everyday basis throughout the world and beyond is ample evidence that these assumptions are quantitatively correct. Put another way, without making the adjustment of the clock rate on the satellite, it would not be possible to achieve the accuracy in the measurement of the elapsed time ΔT required to make the navigation technique useful.

As a final remark on this subject, it should be pointed out that the clock rate adjustment is made in practice by changing the frequency of the atomic clock prior to launch. In fact. this "physical" adjustment is unnecessary. The unadjusted clock could be used instead and the time it measures could simply be corrected by multiplying it by the appropriate conversion factor to make it agree with the ground clock at all times. There is an additional advantage to using this procedure, namely that the conversion factor could be varied in real time on the basis of the current speed and position of the satellite. That would take care of any inaccuracies that occur because the rate of the satellite clock varies with changes in its orbit.

21) Summary: For more than a century, scientists have touted Einstein's relativity theory as one of the greatest achievements of the human mind. One of its most revolutionary characteristics is its claim that space and time are inextricably mixed. This runs contrary to the teachings of Newton and his contemporaries who held that space and time are totally separate entities, a view that dominated scientific thought for over 200 years. The centerpiece of Einstein's theory is the Lorentz transformation (LT), which was already discovered by Larmor and Lorentz a few years before his landmark paper in 1905. Space-time mixing is an essential aspect of this transformation, and was generally thought to be essential for explaining the experimental finding that the speed of light is the same for all observers independent of their state of motion or that ofthe source of the light.

It is nonetheless easy to show that the LT is self-contradictory and therefore unacceptable, thereby rendering Einstein's version of relativity to be physically untenable as well. The problem is that as a consequence of the Lorentz transformation, one must expect two well-defined phenomena to occur: remote non-simultaneity of events for two observers and proportional time dilation of their respective clocks. The latter effect demands that the elapsed times measured by the two observers in relative motion differ by a non-zero factor X, i.e. $\Delta t' = X\Delta t$. Yet remote non-simultaneity requires that if one observer finds two events to occur simultaneously ($\Delta t=0$), the other must find that they occur at different times based on his clock ($\Delta t' \neq 0$). In order to believe both predictions of the theory, it is therefore necessary to abandon the fundamental axiom of algebra that multiplication of any number (X) by zero can only result in a value of zero as well.

There is a straightforward way to correct Einstein's error, however. One has to give up on the space-time mixing concept of the LT and still insist on satisfying both of his two postulates of relativity. The key fact is that because the clocks in relativity theory are assumed to be inertial, i.e. not subject to unbalanced external forces, they must not only move with constant speed and direction, in accord with Newton's First Law of Motion, *they also must have constant rates.* This means that the *ratio* of the rates of any two inertial clocks will also be constant, however, and therefore that their respective elapsed times for any given event must satisfy the simple proportionality relation: $\Delta t' = \Delta t/Q$, where Q is a constant which is specific for each pair of rest frames. *This amounts to a third postulate of relativity.* What has not been understood over the past 100 years is that there exists a different Lorentz-type space-time transformation which is consistent with all three postulates. The above relation between elapsed times in different rest frames is one of its four equations. The new transformation has been named the GPS-LT in recognition of the fact that it is directly relevant to the operation of the Global Positioning System. It is obvious from the above equation for elapsed times *that the GPS-LT eschews the space-time mixing required by the LT*. It clearly excludes any possibility of remote non-simultaneity since whenever $\Delta t=0$, the corresponding elapsed time in the other rest frame must be zero as well.

The $\Delta t' = \Delta t/Q$ relation is not just a theoretical assumption, however. It has been verified in numerous experiments without exception. The results of the Hafele-Keating study of atomic clocks carried onboard circumnavigating airplanes, for example, can be described by means of a simple proportionality relation: $\Delta t'\gamma(v')=\Delta t\gamma(v)$, where the speeds v and v' of the clocks are defined relative to the earth's center-of-mass (ECM). The same equation holds for the periods of clocks mounted on a rotor in the Hay et al. experiment carried out in 1960. The UTDL is easily converted into the GPS-LT time equation by defining the constant Q to be the ratio $\gamma(v')/\gamma(v)$. The latter can be thought of as a *conversion factor* for changing one elapsed time into the corresponding value in another rest frame.

The revised theory based on the GPS-LT subscribes to a different version of the Relativity Principle. It agrees with Einstein that the laws of physics are the same in each inertial system but it also allows for the fact that *the units in which these laws are expressed change in going between rest frames.* Someone moving along with an atomic clock will be unable to notice any change in its rate with acceleration, consistent with Galileo's original definition. The rate does change, however, and this can be measured by another observer in a different state of motion. That observation is key to the success of GPS since it implies that the rate of a clock located on a satellite needs to be adjusted if it is to continue to run at the same rate it had prior to launch.

Dec. 4, 2017

(Corrections made on Jan. 14, 2018)