

without Pain: The Skin began to appear yellow, and Pustles appear'd, like Bladders, on his Finger; which being prick'd, emitted a sanious Liquor. In two Days time all his Symptoms vanish'd, and he became perfectly well.

June 30, the Gentlemen of the Faculty met again, when we tried several Experiments on *Puppies, Cats,* and *Pigeons*; wherein we found the Efficacy of Mr. *Oliver's* Specifick, and gave the Company great Satisfaction. I therefore recommend him to Lovers of Natural Philosophy, and such who study the Benefit of Mankind. I think he deserves Encouragement, that the Specifick may be more universally known.

Ste. Williams, *M. B. F. R. S.*

VII. *A Proposal for the Measurement of the Earth in Russia, read at a Meeting of the Academy of Sciences of St. Petersbourg, Jan. 21. 1737. by Mr Jos. Nic. de L'Isle, first Professor of Astronomy, and F. R. S. Translated from the French printed at St. Petersbourg, 1737. 4to. By T. S. M. D. F. R. S.*

Necessity, or the Exigencies of Geography and Navigation, put Mankind very early upon the Enterprize of measuring the Earth. For how is it possible to construct the Charts of each Kingdom or Empire, without setting down all the Places in
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their true Distances, by the Measures made use of in each Country: Such as were the *Stadia* of the Ancients, and such as are our Miles, Leagues, Wersts, &c. And how could different States be compared with one another, so as to come at the Knowledge of the Spaces they severally occupy on the Earth's Surface, without knowing the Number of these common Measures contain'd in a Degree, or in the whole Extent of the Earth? Hence proceeded the twofold Method of determining the Situation of the different Parts of the Earth, either by their mutual Distances set down in the Measures made use of in each Country, or express'd in Measures common to all, as Degrees, Minutes and Seconds, by marking the Longitude and Latitude of each Place.

Upon the first Determination of the Magnitude of the Earth in Geographical Measures, as in *Stadia* and *Arabian* Miles, the Ancients did not employ any great degree of Exactitude. They were content to set down the Circumference of the Earth, and of its Parts, in round Numbers; probably, because they did not expect to be able to attain much Preciseness in a Research of this Nature. But according as their Desires of improving Geography encreased, by entering into a Detail of it, they found it necessary to have a more exact Knowledge of the Magnitude of each Degree, not only in great Measures, as in Miles and Leagues, but also in Pearches, Toises and Feet; which could not be done otherwise than by Geometrical Operations and Astronomical Observations, more exact, and consequently more operose, than had been, or indeed could have been undertaken before.

I shall not enter here upon a detail of the immense Labours of modern Mathematicians on this Head, as those of *Fernel* in *France*; of *Snellius*, *Blaeu*, and *Muschenbroek* in *Holland*; *Norwood* in *England*; Father *Riccioli*, and lately *Monsignor Bianchini* in *Italy*; and the Gentlemen of the *Academy of Sciences* in *France*; to get only the precise Magnitude of a Degree in the Measures of their respective Countries. But I will answer an Objection which might be raised hereon, *viz.* That it was needless to undertake these same Operations in so many different Places, since the Magnitude of a Degree once determined in the Measures of any one Country, may be easily reduced to the Measures of any other, by the exact Knowledge we now have of the Proportions of modern Measures. Whence it might be inferr'd, that after all the Exactness which the Astronomers of the *Royal Academy of Sciences* of *Paris* have obtain'd by their Labours, in drawing their Meridian from one Sea to the other, it is unnecessary to enter upon a new Undertaking of the same Thing any where else: since, in order to reap the Advantage of that Work for the Geography of each particular Country, nothing more is requisite than exactly to compare the Measures of those Countries, with those made use of by the *French* Astronomers in their Operations and Calculations.

Now, taking *Russia* for the Example, the Geographical Measures of which are *Wersts*, divided each into 500 *Sagènes*, and each *Sagene* supposed to be exactly seven Feet *English*; this Relation once known, as also the exact Relation of the *English* to the *French* Foot, or to the Toise of six Feet, which the *French* Astro-

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nomers employ'd in their Measurements, and of which they found a Degree of a great Circle contain'd 57060; what more is requisite for concluding that a Degree of a great Circle contains $104 \frac{1}{2}$ *Wersts*? And what remains towards the Perfection of the Geography of *Russia*, in the most minute Detail that can be enter'd upon, but to employ this Measure of *Wersts*, *Sagenes*, and *English* Feet, (if you please) in actual Measurements; and to construct the Charts by the most exact Methods of Geometry; taking care to set them down right, as to their true Bearings, and to regulate them by the most exact Astronomical Observations of Longitude and Latitude that can possibly be made.

It must be confess'd, we should be very happy, if in the Geography of *Russia* we were arrived at this Pitch; not only in the general Map, but likewise in that of any particular District whatsoever, the nearest and of most Concern to us. But besides that we are as yet far from pretending to this; I will now make appear that it is not possible to attain it, without undertaking an equal, and even a greater Work than all that has been hitherto done in *France* and elsewhere, towards the Measurement of the Earth. I am myself affrighted at the very Thought of what I propose, and am under Apprehensions that it will give the same Pain to those of the Company, who know, as well as I, the prodigious Labour in which this Work must engage the Undertakers. But what is not a Person capable of undertaking for the Glory and Interest of her Imperial Majesty, when excited by the Benefits she heaps on the Academy, and by the singular Protection her Ministers grant to this Body and the Sciences

Sciences therein cultivated! Sufficient Motives for undertaking Matters of the utmost Difficulty.

When I said above, that an exact Knowledge of the Magnitude of a Degree of the Earth in any known Measures of one Country was sufficient for constructing exact Charts of all other Countries, only having a Regard to the different Proportion of the Measures; that is to be understood upon a Supposition of the Earth's being perfectly spherical: seeing it is well known, that in a Sphere the Degrees of all the great Circles are every where equal; and that we likewise know, in a Sphere, the Proportion of the Degrees of the small Circles to their great Parallels, according to their Distance from them.

But if the Earth be not perfectly spherical, the Case is quite alter'd: All the Degrees of the great Circles will not be equal to one another; and those of the small Circles, taken at a certain Distance from their parallel great Circles, will not have the same Relation that the Degrees of the small Circles, taken at the same Distance, would have on a Sphere. In all this there might possibly arise an infinite Variety, according to the Figure the Earth might have; and as it is not yet decided what is the Earth's true Figure, and that there is no better Method of ascertaining it than by Observations made in so great an Extent as that of *Russia*: For these Reasons I have advanced, that the Perfection of the Geography of *Russia* stands in need of this great Undertaking; which, besides the Usefulness of it, will acquire much Honour to the Academy of *Petersbourg*; if that Body can, by means of this Work, contribute towards the deciding the celebrated
 Question.

Question of the Earth's Figure. But before I enter into a Detail of the great Advantages of this Research, and the Nature of the Operations I propose, it is necessary to explain in what Manner I mean that the Question of the Earth's Figure and Magnitude is not yet decided.

There have been some who have long since suspected, and even thought they were furnished with Proofs of the Earth's not being exactly spherical. I here entirely abstract from the Unevennesses of its Surface, which are not sensible in regard of the Earth's whole Bulk; seeing the Tops of the highest Mountains, and those even few in Number, are scarce more than a League above the Level of the Seas. Wherefore, I suppose the Earth to be bounded by a Curve Surface, such as it would be by the Level of the Sea carried quite over all the Earth. 'Tis in this Manner, the Earth being consider'd as cover'd with a Fluid, that Sir *Isaac Newton*, in the first Edition of his *Principia*, publish'd in 1686, has demonstrated, that supposing this Fluid homogeneous, and the Earth to have been at rest at the Time of its Creation, it must have assumed the Figure of a perfect Sphere: But afterwards, supposing it to have a Motion on its Axis, as is well known it has in 24 Hours; this spherical Figure must have been changed into that of a Spheroid, flatt'd at its Poles, in which the Degrees on the Meridian must be greater drawing near the Poles, than near the Equator.

Sir *Isaac* confirms this Hypothesis of the Earth's Figure, by Observations of the Diminution of the simple Pendulum upon approaching the Equator: To which Dr. *Pound* adds the Analogy the Earth has with some of the other Planets, as *Jupiter*, which sometimes

times appears oval, its least Axis being that about which it makes its Revolution.

This Opinion of Sir *Isaac* has likewise been maintain'd by Mr. *Huygens*, though with some small Difference. But in 1691, Mr. *Eisenschmid* * having compared the Measurements of the Earth made in different Latitudes, as that of Father *Riccioli* in *Italy*, of Mr. *Picart* in *France*, and of *Snellius* in *Holland*; and having found that the Degree, which resulted from those different Measurements, continued to grow less in drawing nearer the Poles, (which is quite the contrary of what follows from the Earth's Figure supposed by Sir *Isaac* and *Huygens*) Mr. *Eisenschmid* was thereupon of Opinion, that the Earth was longer at the Poles.

This Opinion of Mr. *Eisenschmid* was afterwards confirm'd by the late Monf. *Cassini*, in the Observations of the Meridian of *Paris*. For in 1701, having carried on these Operations to the *Pyrenean* Mountains, which is a Space of above seven Degrees and a half, he found, that as he advanced to the South these Degrees encreased $\frac{1}{800}$ Part, or 72 Toises each Degree.

Since the Meridian of *Paris* was, in 1718, carried on Northward to the Sea, Monf. *Cassini*, the Son, found, upon comparing more than eight Degrees, which this Meridian contains from Sea to Sea, that the Increase, going Northward, was but from 60 to

* Jo. Casp. Eisenschmidii Diatribe de figura telluris Elliptico-Sphaeroide; ubi unà exhibetur ejus magnitudo per singulas dimensiones, confensu omnium Observationum comprobata. Argentorati, apud Joh. Frider. Spoor. 1691. 4to. (pag. 54. cum fig.)

61 Toises each Degree; as may be seen in the large Treatise publish'd in a separate Volume, as a Sequel to the Memoirs of the *Royal Academy of Sciences of Paris* for the Year 1718. These Reasons did not hinder Sir *Isaac* from persisting in his first Opinion of the Figure of the Earth flatt'd at the Poles, as appears in the 2d and 3d Editions of his *Principia*, publish'd in 1713 and 1726: And 'tis very surprizing, that by this very Figure of the Earth he demonstrates a certain Motion it has, to explain in the *Copernican* System the Precession of the Equinoxes, or the apparent Motion of the fixt Stars in Longitude. Sir *Isaac* finds the Inequality of the Degrees on the Meridian, in so little an Extent as that of *France*, not sensible enough to be possibly determin'd by immediate Observations; and he is of Opinion, that we ought more to rely on the Observations of the simple Pendulum, and on the other Principles which he has built upon, to conclude the Earth flatt'd at the Poles.

In 1720, *Monf. Mairan* attempted to reconcile the two different Hypotheses of Sir *Isaac* and *M. Cassini*, by imagining that the Earth, at its Creation, being without Motion, was of a much more oblong Figure than that which *Cassini* thinks it has at present; so that it might have been reduced to that which it now has, by the diurnal Motion on its Axis, &c. But *Dr. Desaguliers*, who is of Sir *Isaac's* Opinion, has made appear, in the *Philosophical Transactions* for 1725, N^o 388. that *Mr. Mairan's* Supposition is contrary to the Laws of Motion; and has moreover propos'd several considerable Doubts on the Observations and Suppositions employ'd by *M. Cassini* in his Determination of the Earth's Figure in 1718.

As soon as the Meridian of *Paris* had been extended from one Sea to the other, and M. *Cassini* had thence deduced a Confirmation of the System of the Earth's being longer at the Poles; I imagined a new Method of deciding the Question, by the Observation of the Degrees of the Parallel compared with those of the Meridian.

For that Purpose I consider'd, that as the Degrees of the Meridian and those of the Parallel, at the same Elevation of the Pole, had different Relations, according to the different Figures ascribed to the Earth; nothing more was requisite for concluding which Hypothesis was the true one, than to determine this Relation by immediate Observation.

Having supposed, that there had been observed on the Parallel of *Paris*, a Space nearly of the same Magnitude with that on the Meridian, that is, of about 13 Degrees, since that on the Meridian is about eight $\frac{1}{2}$ Degrees; I found by an exact Calculation, that according to the Figure which M. *Cassini* has given to the Earth, this Space ought to contain thirteen Minutes and half of the Parallel more than in the Hypothesis of the Earth's being spherical; which appear'd to me considerable enough to be able to decide between these two Hypotheses, and by a stronger Reason between the Hypotheses of *Newton* and *Cassini*; seeing the Difference ought to be still more considerable than that now specified.

I concluded, at least, that, independent of the Figure of the whole Earth, which could not be determined by the sole Observations made in *France*, without making Suppositions, and admitting Principles, which are still liable to be contested; it would be of great Consequence

quence towards constructing exact Charts of the Kingdom, to ascertain this Relation by Observations, which consisted only in forming Triangles along the Parallel of *Paris*, and observing at the two Ends the Difference of the Meridians, by the most exact Methods.

The Difference, which I have now mention'd, seem'd to me to be so considerable, that I was in hopes of being able to determine it by Means only of two Places within Sight of one another, and situate to the East and West; provided their Difference of Longitude were accurately observed, independently of Astronomical Observations, by means of lighted Fires; after the Manner that M. *Picart* put in Practice in *Denmark*, for determining the Difference of Longitude of the Astronomical Tower at *Copenhagen* and of *Uraniburg* in the Isle of *Huen*. With this Intent, in the Month of *April* 1720, I went some Distance from *Paris* Southward, to the Places which I judged most proper for my Purpose; but my Design was not then executed, for want of Assistance, and for other Reasons, which I shall pass in Silence.

Since that Time, I saw with Pleasure, that the Marquis *Poleni* had hit upon the same Thought with me; as may be seen in his Letter to the Abbot *Grandi*, dated in *November* 1724.

The Decision of this famous Question of the Earth's Figure had stop'd there, when in the Year 1733, the Minister of *France* having thought it necessary to construct an exact Map of the whole Kingdom; and being inform'd, that the Work could not be better carried on than by the Astronomers of the *Royal Academy of Sciences*, applied to M. *Cassini* on that Head; who

who was of Opinion, that, in order to execute it with the utmost Exactitude, the same Method ought to be employ'd as for the Meridian, by taking through the whole Extent of the Kingdom, Triangles link'd together by means of Objects seen successively one from another, &c. This Project of making a Map of *France* by such Triangles, had been already offer'd to *Monf. Colbert* by *Monf. Picart* in 1681, but was not then executed. However, *M. Cassini* proposed, that these Triangles should be begun in a Direction perpendicular to the Meridian; in order to render these Operations of Service towards the Decision of the Earth's Figure, pursuant to the Method which I spoke of above: And *M. Cassini*, having in Person undertaken these Operations, and having carried them that same Year, 1733, from *Paris* to *St. Malo*, whose Longitude from *Paris* *M. Picart* had observed in 1681; the Relations of the Degrees on the Meridian and Parallel were found to be such as were required in the Hypothesis of the Earth lengthen'd at the Poles, and even more lengthen'd than *Cassini* had determin'd in 1718. For instead of the Diminution of a sixtieth Part for each Degree of the Parallel, which I had found according to the Earth's Figure, as determined by *Cassini* in 1718, he deduced from his Operations in 1733, a Diminution of the 36th Part of each Degree.

True it is, that *M. Cassini*, in the Account he gave of this Determination at the publick Meeting of *November 14, 1733*, does not give it as entirely sure; because the Longitude of *St. Malo*, with regard to *Paris*, was collected but from one Observation only of *Jupiter's* first Satellite, wherein there may possibly
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be some Error : But at least M. *Cassini* seems certain, that there is a very considerable Diminution in the Degrees of the Parallel of *Paris*, which confirms his Opinion of the Earth's being longest at the Poles. This we are likely to have a better Certitude of hereafter, seeing we are inform'd that this Measurement of the Parallel of *Paris*, is carrying on in *France* by M. *Cassini's* Sons, M. *Maraldi's* Nephew, and several other young Mathematicians, instructed by M. *Cassini* in this sort of Work.

I have already said, that all these Operations perform'd in *France*, for the Figure and Magnitude of the Earth, could not serve to determine the Earth's Figure out of *France*, without the Assistance of certain Hypotheses ; unless the same thing were undertaken and carried on in the other Regions of the Earth, more Northern and Southern than *France*. 'Tis upon this Consideration, that the *Royal Academy of Sciences* took up the Resolution of sending some Astronomers to make the like Observations as near the Equator and the Poles as possible, which are the Places where the difference of the Degrees on the Meridian ought to be the greatest, according to the different Hypotheses.

In the Month of *April* 1735, set out from *France* three Mathematicians and Astronomers of the Academy, viz. Messieurs *Godin*, *Bouguer*, and *De la Condamine*, for the Province of *Quito*, which is the most Northern part of *Peru* in *America* ; in order to observe, just under the Equinoctial Line, the Magnitude of some Degrees of the Meridian and Equator.

As to the other Mathematicians and Astronomers of the same Academy, viz. Messieurs *de Maupertuis*,
Camus,

Camus, *Clairaut* the Son, and *Monnier* the Son, who have been sent to the North, they departed from *France* in *April* of last Year 1736, with Mr. *Celsius*, Professor of Astronomy at *Upsal*, who accompanied them to *Sweden*, as far as the Bottom of the Gulph of *Bothnia*, where they might measure about a Degree on the Meridian at its crossing the Polar Circle. But as, by the last News I received from them, they had not finish'd their Operations, 'tis not yet known whether the Magnitude of the Degree measured by them, favours the Opinion of M. *Cassini*, or that of Sir *Isaac Newton*. All we know is, that they have found the length of the simple Pendulum favourable to the latter, that is, longer under the Polar Circle than farther South. My Brother *De la Croyere*, had already found the same Thing: For being at *Archangel* in 1728, he there observed, in the most exact Manner he possibly could, the Length of the simple Pendulum, which he found to be $\frac{3}{10}$ Parts of a Line longer than at *Paris*.

We are likewise informed by the other Astronomers gone to *Peru*, that in their Way towards the Equator, being at *St. Domingo*, in the Latitude of 18 Degrees 37 Minutes, they there found the Pendulum swinging Seconds, to be about two Lines shorter than at *Paris*. Thus, all we as yet know from those Gentlemen, on the Expeditions to the North and the Line, confirms the Opinion of Sir *Isaac Newton* and his Adherents: And yet M. *Mairan*, whom I have already mentioned, pretends, that this shortening of the Pendulum in drawing nearer the Equator, is in one Sense entirely independent of the Earth's Figure.

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Thus it appears from the foregoing Account, that the Question concerning the Earth's Figure is not yet at an end. Nay, 'tis not impossible, that after finishing all the Observations which are actually making, new Difficulties may arise, and new Objections be started, that may prevent its being entirely decided. However, all this Work cannot fail giving great Light to this important Question, and procuring considerable Advantages to Geography, Astronomy, and natural Philosophy.

'Tis with this View, and particularly to render such important Service to the Geography of *Russia*, that I think it necessary to undertake a Work of that Nature in *Russia*; towards executing which we have great Advantages, which the other Nations have not. One of the principal of these Advantages is the great Extent of *Russia* every way. For were the Meridian of the *Imperial Observatory* of *Petersbourg* to be determined, it might be carried to between 22 and 23 Degrees; which is a fourth Part of the Distance from the Pole to the Equator. The Meridians of *Mosco* and *Astracan* are not of less Extent; and consequently we might, by the Measurement of some one of these Meridians, determine more exactly than could have hitherto been done, the Inequality that subsists between the Degrees of the Meridian.

This is what the great *Cassini* wish'd, when, after having, in the Year 1701, determined this Inequality by the extent of seven Degrees observed in *France*, as has been mention'd above, he says, that this Fact might be verified by Measurements of greater Extent, if the other Princes of the Earth did contribute as
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much as the *King of France* towards the perfecting of Sciences.

M. Cassini was then ignorant of the Views which *Peter* the Great had formed in the Establishment of the *Academy of Sciences* at *Petersbourg*; nor could he then foresee that her present Imperial Majesty, who now so gloriously governs in the Empire of *Russia*, was destined not only to pursue the Designs projected by that great Monarch, but also to ripen them to Perfection, by granting such Succours and Assistances for the promotion of Science, as were never yet afforded from any of the greatest Princes of the Earth.

In the great Extent which might be given to the Meridian of *Petersbourg*, as abovesaid, there would be the Advantage of knowing, by Operations link'd together, or uninterrupted, the Magnitude of some Degrees equal to those which have been measured in *France*, and to that which the *French* Astronomers have measured in *Sweden*; and not only all the Degrees between the two, which the *French* Astronomers have not had in their Power to observe, but also some Degrees farther Northward than that measured by them in *Sweden*.

As the Exigencies of Geography require the Triangles, taken for the Determination of the Meridian, to be continued on every Side, and principally in Directions perpendicular to the Meridian, or according to the Parallels; with how great Exactitude may we not then determine the Proportion of the Degrees on the Parallels to those on the Meridian, by means of the vast Extent of the *Russian* Empire, which on its Western Side extending as far as all the Dominions of *Europe* from the most Northern to

the most Southern, has no others Bounds to the East than the East itself, if I may be indulged the Expression; seeing its Extent that Way contains near half the Earth?

Another great Advantage to be obtain'd by the Work I now propose to be made in *Russia*, is, That, we coming after others, shall reap the Benefit of all their Knowledge and Experience in the like kind of Measurements: Whence we may expect to succeed and execute it better than could have been done elsewhere, by applying timely Remedies against the Difficulties that occur'd in other Places.

These Operations are to be founded on a Basis of the greatest Length possible; which must be actually measured, and with the greatest Exactness that may be; as it is to serve for a Foundation to the Measurement of all the Triangles. And in this Point too we have a very great Conveniency near *Petersbourg*, seeing on the Ice here we may measure out a Basis, greater than has been hitherto taken, namely, from the Coast of *Ingria* about *Peterhoff*, to the Coast of *Finland* toward *Systerbeck*. There is not less than 20 Wersts Distance between these two Extremities, and this great Distance may be measured very exactly, this Year especially, that the Ice is very even. Moreover, as this Basis is situate between the Isle of *Cronstad* and *Petersbourg*, in a Direction nearly perpendicular to the Distance from *Petersbourg* to *Cronstad*; there can be no better Method for inferring thence, by exact Observation of the Angles taken at the Extremities of this Basis, the Distance from the Centre of the Imperial Observatory to the Steeple of the new Church of *Cronstad*; which two Objects are seen reciprocally from each other, and are not less

less than 30 Werfts asunder: And this Distance once known exactly, will serve as a Foundation for all the Triangles that are to be taken; of which each of the Sides may have not less than from 30 to 40 Werfts, according as we shall find Objects advantageously situate for that Purpose. We have, to begin with, the Mountain of *Douderhof*, which, with the Imperial Observatory, and the Steeple of *Cronstad* Church, forms one of the most convenient Triangles imaginable for the Subject we propose.

In taking Observations at these three Places, we shall see if we can discover others of the same advantageous Situation; but when no remarkable Objects are found of the Situation and Distance sought for, they must be erected on purpose, in the same manner as was of necessity done in other Countries: And this may be done here with more Ease, seeing, in Places where the Woods intercept our Sight, small Towers may be raised, at very little Expence, out of these same Woods, with Signals placed on them, which may be seen as far as may be required. In open Places, where consequently Wood is not so common, Signals alone, without Towers, will suffice.

The most necessary Instruments for executing this Undertaking, are, besides the ordinary Astronomical Instruments, a common Quadrant of between two and three Feet *Radius*, for observing the Angles of the Triangles that shall be taken; and a Portion of a Circle of the greatest Radius that can be conveniently had, for observing the Arches of the Heavens corresponding with the Distances measured on the Earth.

I say, the Quadrant ought not to have a Radius of more than between two and three Feet: For if it be

bigger, it cannot for the most part be made use of in Steeples and other Places of considerable Height, where 'tis requisite to observe; but also if it be less than two Feet, it will not give the Value of the Angles with sufficient Exactness.

As to the other Instrument for observing the Arches of the Heavens, its Radius ought not to be less than from twelve to fifteen Feet: but 'tis not necessary that it should contain a large Portion of a Circle. 'Tis only requisite to have this Portion somewhat larger than the Arch of the Heavens intended to be measured. Thus, as the Meridians, which may be traced in *Russia*, can be extended but between 22 and 23 Degrees, as already mention'd, it will suffice, that the Instrument employ'd therein be a Portion of a Circle of 30 Degrees.

M. *Picart*, for his first Operation, got an Arch of a Circle made of 18 Degrees and of 10 Feet Radius, with which he thought himself sure within two or three Seconds: And no other Instrument was made use of in the chief Observations for the Meridian of *Paris*. The Astronomers who are gone to *America*, carried with them an Instrument of twelve Feet Radius, and of a Portion of a Circle of 30 Degrees. But those come to *Sweden*, contented themselves with a Portion of a Circle of five $\frac{1}{2}$ Degrees, and nine Feet Radius: But this Instrument, made by Mr. *George Graham*, a very able *English* Mechanician, is by its Construction so exact, that the Astronomers who have used it, think themselves sure to two Seconds. The one we want for the Observations in *Russia* ought to be made by the same Artist, and of the same Construction.

'Tis

'Tis with such an Instrument that Mr. *Bradley*, a celebrated *English* Astronomer, has discover'd, in the Meridian Altitudes of some fixt Stars, certain constant and annual Variations, which do not proceed either from the Variation of the Refractions, or from the Parallax of these Stars, or, in fine, from any Nutation or Wavering of the Earth's Axis; but which he accounts for by the successive Motion of Light.

Whatever be the Cause of these Variations, (which Cause, as well as its Effect, are not as yet, perhaps, entirely cleared up), as they may possibly happen in the Space of Time requisite to be spent in making the Observations for the Meridian, or in passing from one End of the Meridian to the other; it is necessary, with the same Instrument, or such another, that is of pretty near the same Exactness, to examine the Variations of the Stars made use of: Wherefore it would be of considerable Advantage, not only for the Observations of the Measurement of the Earth, but also for all the other principal Researches in Astronomy, to have Orders given for procuring two mural Quadrants of Mr. *Graham's* Make, and of the same Construction, as I have already specified; for which there are Walls already rais'd at the Imperial Observatory, in the Plane of the Meridian.

With these two Quadrants, which might be of seven Feet Radius, and the moveable Telescope nine or ten Feet long, we should be in a Condition to make Observations of the utmost Accuracy, such as the present State of Astronomy requires.

Besides these Instruments now mention'd, which are of absolute Necessity to a solid Establishment of Astronomy and Geography in this Country, there are still

still some other smaller Instruments, that may be of great Use in the Operations I propose, or may serve to make other curious and useful Observations at the same time that those for the Measurement of the Earth are making.

When the Sides of the Triangles, taken for measuring the Earth, terminate at very elevated Places, as on the Tops of the highest Mountains, it is necessary to reduce these Triangles to what they would be, had they been observed in horizontal Planes situate upon a Level with the Sea. For this Purpose, we must know the Height of the Mountains above the Sea's Level, which cannot always be determined geometrically, or would at least be too tedious to perform: Wherefore, in the Meridian of *Paris*, which cross'd very high Mountains, M. *Cassini* was of Opinion, that he ought to fix their Height by a shorter Method, which is that of the Height of the simple Barometer, observed on the Top of each Mountain, and compared with that observed at the same time in another Place, whose Elevation above the Sea's Level was known. But as that Method supposes the Knowledge of the Proportion which the different Fallings of the Mercury keep with the different Heights to which the Barometer is carried; and as natural Philosophers are not as yet entirely agreed on this Head, for want of Observations of sufficient Accuracy: Thence it happen'd, that Dr. *Desaguliers*, making appear that Mr. *Cassini* has not employ'd the most exact Proportion, found Reasons for correcting, or at least for doubting, of some of M. *Cassini's* Calculations. Thus it must be by the Assistance of new Experiments, better circumstanced than those hitherto made, and pur-
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fuant to a Theory entirely agreeing with these Experiments, that this Method may be employ'd with Certainty, for determining the Height of Mountains by the Barometer, and reducing the Angles observed from the Tops of these high Places, to what they would be, if they had been observed on a Plane horizontal with the Level of the Sea. Now these new Observations can be made on our Way in tracing the Meridian; and for that Purpose I have begun to construct compound Barometers, which, by their peculiar Make, being very nice, will serve to observe with Accuracy the Quantity of the Mercury's Fall at the different Elevations to which they shall be carried, in order to fix with greater Certainty the Proportion of that Fall. I shall take particular Care in the Construction and Use of these Instruments to provide a Remedy against the Effect of Heat, which, as it is different in the different Times and Places of making these Experiments, may possibly produce apparent Variations, of which 'tis necessary to keep an Account.

There is still another Method of determining the Elevation above the Level of the Sea of all the Points, in which the Triangles terminate, that are made for the Measurement of the Earth. This may be done by beginning these Operations near the Sea, as I propose to do, and actually measuring how many Toises and Feet the Places of the first Stations are elevated above the Level of the Sea. For if the Angles of the apparent Elevations of the second Stations seen from the first be afterwards observed, it will be an easy Matter, from the known Distances, to deduce the true Elevations of the latter
above

above the former, and consequently above the Sea's Level, making proper Allowances in the Calculations for the Difference of the apparent Level from the true one. In this Method nothing is to be apprehended but the Variation of Refractions; but for this a Remedy may be found, for the most part, by returning upon one's Steps, that is, by reciprocally observing the first Stations seen from the second: For if it be found, that as much as the second Station appears elevated above the first, so much the first is depress'd below the second, except the small Difference which must arise according to the given Distance, it will be a Proof, that the Refraction has been of no Prejudice.

The Observations and Determinations of the true Heights of all the Places which are to be visited, will not be the least laborious of those that are to be made in these Journies; but then their Usefulness will be a sufficient Recompense for the Trouble; seeing they will afford us the Means of knowing all the chief Unevennesses of the Ground traversed by these great Triangles, which being compared with the Length of the Course of the Rivers, may give us room to judge of their Rapidity, of the Ease or Difficulty of their Communications, &c.

The other considerable Observations and Experiments to be made in the Journies undertaken for such Enquiries, are, the Observations of the Magnetic Needle, both as to its Dip and Variation: But chiefly the Observations of the Length of the simple Pendulum, which, at present, is become requisite to be observed with as much Exactness, and in as many Places as is possible; but also for which there are new Methods

thods invented, that we are promised the Communication of, and which probably surpass those hitherto made use of; in as much as, since those Methods have been found by the *Royal Academy of Sciences of Paris*, it was thought proper to notify them to the Astronomers sent to *Peru*, in order to put them in practice in their Observations.

Whereas all these Operations and Observations, which I have here proposed, however arduous and difficult they may prove, have no other End than the Benefit of Geography; those who are to have the Management of this Enterprize must be attended by several Surveyors and other Mathematicians of this Nation, who are to be instructed on the Road, and employ'd at the same time in lesser Operations with smaller Instruments: By which Means the Maps of the Countries, taken in by these great Triangles, may be verified; and thus, according as this Work advances, the finishing Stroke may be given to the Charts of *Russia*.