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INTELLIGIBLE SIGNALS BETWEEN NEIGHBOURING STARS.

CONSIDERABLE interest attaches itself to methods of communication which have been devised under the pressure of necessity, to take the place of speech and writing. Many memoirs have, consequently, been written on such topics as the gesture language of savages, or that of deaf mutes, or on the alphabetical tappings of prisoners upon the walls that divide their solitary cells, or on Laura Bridgeman and a few like her, who, though destitute of all other senses, have, nevertheless, been educated to a high level of accomplishment by touch alone. In most of these cases the method of instruction is by "trial and error." The pupil makes many guesses, the wrong ones are negatived by his teacher with a gesture of impatience, the right one is welcomed approvingly. But no help can be obtained from this method in the task I have set myself to perform. Signals have to be devised that are *intrinsically* intelligible, so that the messages may be deciphered by any intelligent man, or other creature, who has made nearly as much advance in pure and applied science as ourselves. It may seem at first sight almost impossible to do this, but it is quite otherwise, and the reader will probably feel surprised at the unexpected simplicity of this curious problem.

I may as well mention how it came into my thoughts. Some four years ago the planet Mars made a near approach to the earth, and presented a splendid spectacle at night. The possibility of exchanging visible signals with Mars was then discussed in the newspapers, apparently with the result that it was not altogether inconceivable that signals might be sent, though the difficulties of doing so would be enormous. Then the very different question arose of "*cui bono?*" to which there was a general response that nothing more could possibly be learnt on either side than that intelligent folk existed on the other planet, who were observant, mechanical, and capable of acting in unison upon large undertakings. For my part, I considered that limitation unjustified, and amused myself with thinking out the ground-plan of the present article. In the meantime the craze about Mars died away; the planet ceased to be particularly conspicuous, people grew tired of the topic, and the heated thoughts of many writers were cooled by copious douches of astronomical common sense. The subject having ceased to interest others, I laid up my ideas presumably for perpetuity, but an accident revived them. I was compelled last summer to spend a somewhat dreamy vacation, beginning with a course of hot baths at Wildbad, and its relaxing accompaniments (for the good effects of which I am truly grateful), when being unable to occupy myself otherwise than in a desultory way, I did so by developing my previous notions.

The simplest way of explaining my method is to suppose that Mars began to signal, to the wonderment of our astronomers, who sent descriptive letters to the newspapers from day to day, out of which the following imaginary extracts are taken :—

1. Astronomers in various observatories have been much excited of late by the sight of minute scintillations of light proceeding from a single well-defined spot on the surface of Mars, and they are becoming greatly perplexed as to the significance of this strange phenomenon. It is hoped that the Director of the X. high-level observatory, where the atmosphere is singularly transparent, which is favourably situated for now observing the spot in question, and which is furnished with a telescope peculiarly well suited for examining Mars, will soon be able to tell us something more about it. In the meantime it is well not to indulge too freely in wild speculation.

2. The Director of the X. observatory is, at last, strongly disposed to believe that the scintillations are purposive ; that they are really intended as signals from the Mars-folk to the earth. He suspects that their signalling apparatus is not yet in working order, that adjustments are being verified, and that what we now see resembles the tuning of instruments before the opera begins. If the signals are produced as they seem to be, by an immense assemblage of large heliographs, the difficulty would be great in drilling the multitude of operators engaged in working them simultaneously.

3. The scintillations from Mars show more firmness and power, but the signalling is still in the earlier stage of preliminary trials. Enough has, however, been seen to show that three and only three different signals are employed, differing in their lengths, and which for brevity may be called *dot, dash*, and *line*. The dot lasts $1\frac{1}{4}$ seconds, the dash $2\frac{1}{2}$, and the line 5 seconds; consequently the mean length of a signal is a trifle under 3 seconds. There have been a few well marked successions of "dot, dash, line"—"dot, dash, line," in which the interval between the several letters, so to speak, is $1\frac{1}{2}$ seconds ; those between words, one of which is here represented by a short bar, are 3 seconds ; those between paragraphs are 6 seconds. This may be accepted as a good estimate of the future speed of signalling, though, of course, the exigencies of experience may show that a slower rate will be needed, or, again, the drill may hereafter be so smartly performed, that the rate will be increased. As there are three varieties of signal, the total number of different words of one letter is 3 ; of two letters, 9 ; of three letters, 27 ; of four letters, 81 ; of five letters, 243, and so on. Also the average times occupied in signalling these words, including the 3 seconds' pause at the end of each, are 6, 10, 15, 20 and 24 seconds respectively. Whatever the Mars-folk may have to say must be briefly expressed, and it seems incredible under these conditions that anything could be communicated by them to us which shall be intelligible and of value. Some persons are disposed to ascribe this immense undertaking to the caprice of a mad millionaire in Mars, or rather to a mad billionaire. There have been instances in the past history of our earth of many gigantic follies, without counting the traditional Tower of Babel.

A recording apparatus is now constructed for our use here, which acts well. A long strip of telegraph paper is slowly drawn by clockwork under a hinged pencil on which the observer rests his finger. When a flash is on, he presses with his finger and the pencil leaves a mark; when the flash is off, he ceases to press, a spring lifts the pencil, and a blank is left on the travelling slip of paper.

4. The signals have improved considerably in regularity and power, and occasional sequences of them have been gone through in a masterly way. So the drilling of the operators appears to be nearly complete, and we may expect soon to see what the system is intended to show. The phenomenon is most extraordinary. If it be effected through the money of a mad millionaire, he must have had the sense to subsidise an uncommonly intelligent director of works.

5. A most eventful night has been passed at the X. observatory. At first the sky was hazy and partly clouded, so Mars was, at the best, but imperfectly seen, and was often quite invisible; then, at half-past nine, all cloudiness disappeared, and the flashes were observed to be proceeding from Mars with greater power and precision than ever before. The whole assemblage of their heliographs must have been simultaneously at work, and the drill was excellent. The signalling continued off and on for more than three hours. The recorder being kept at work the whole time, every signal then made is preserved in a permanent form, of course including occasional mistakes. The records are as yet totally unintelligible, possibly owing to the loss of the first part of the communication, which may have contained the key to what followed. It is noticeable that during the last two hours the signals consisted almost wholly of three-letter words; in the earlier part there was a preponderance of two-letter words, some of four and of five letters, but none of three.

6. A large typed telegraphic dispatch appeared in all the evening newspapers—

COMPLETE DECIPHERMENT OF THE FIRST PART OF THE MESSAGE FROM MARS. Full particulars to-morrow.

(Signed) Director of the X. Observatory.

7. The evening was serene, and the whole of the night continued to be beautifully clear. The experiences of previous days enabled every preparation to be made for the expected event. And it came. First there was a succession of "lines" with intervening pauses, evidently as a note of preparation, and then after a longer pause the message began with the accompanying sentence, which

No. of dots.		Is equal to.	Symbols for Numerals.
(1)	.	—	. .
(2)	. .	—	. —
(3)	. . .	—	. ——
(4)	. . . .	—	— .
(5)	. . . . .	—	— —
(6)	. . . . . .	—	— ——
(7)	. . . .	—	—— .
(8)	. . . .	—	. . —— —
(9)	. . . .	—	. . . .
(10)	. . . .	—	. . . —
(&c.)	. . . . .	—	. . . .

occupied less than six minutes in transmission. The headings and the column on the left, did not form part of the signalling, but are introduced for the convenience of the reader. The message is divided into three sub-divisions by means of pauses. Let us consider the first of these, in which there are seven lines. Every line begins with one or more dots; then follows a dash; and then a word of two letters. There is one dot at the beginning of the first line, two at that of the next, and so on regularly up to the seventh. The symbols at the end of the successive lines are those of the successive combinations of *dot*, *dash*, and *line*, taken in order up to the seventh; the eighth which is —— —, and the ninth, which is —— ——, are not used. The arrangement suggests that the dash means "is equal to," and that the symbols are those of numerals, corresponding to the number of dots at the beginning of the line. So we should read the message as (one dot) (is equal to) 1; (two dots) (are equal to) 2, and so on. Accepting this interpretation provisionally, we see in the second subdivision that the symbols for 8, 9, and 10 are respectively represented by two words, thus 1 ?, 11, 12. The symbol here expressed by ? is the first of the two omissions mentioned above; it stands presumably for 0. This would show that the Mars-folk have not used a decimal system of notation as we do, but one that has 8 for its basis. With much hesitation, we may lastly suppose the four dots at the beginning and end of the line that forms the last subdivision, to mean "&c.," so that line should read, &c. = &c.

These provisional hypotheses are so amply confirmed by the next messages that ordinary figures will be used in place of the actual signals, and our own decimal notation will be employed, having first translated the Mars notation into it. Hereafter, Italic numerals and letters will signify suggested interpretations; after these have been confirmed and established, Roman ones will be substituted.

The second message consists of five lines:—

1 plus 1 (equal to) 2; *1 plus 2 (equal to) 3*; *2 plus 3 (equal to) 5*; *2 plus 5 (equal to) 7*; *3 plus 3 (equal to) 6*.

This goes a long way towards verifying the numerals, and it suggests the symbol for *plus*.

The third message is of a similar form, except that *minus* is substituted for *plus*. It adds so much confirmation to what has gone before that Italics need not be used for the simple numerals 1 to 7, nor for the words "equal to," "plus," and "minus." Each of these two messages occupied about 6 minutes.

Multiplication follows, by which the supposed system of notation with 8 for its basis is confirmed, and the symbol for 0 is established. The signals were, 2 (*multiplied into*) 2 (is equal to) 4; 2 (*multiplied into*) 3 (is equal to) 6. Then, after a double pause, 2 (*multiplied into*) 0 (is equal to) 0; 3 (*multiplied into*) 0 (is equal to) 0. This was followed by a series of higher multiples, such as we, writing in the decimal notation, might phrase as follows (the figures really used being different and accordant with a notation having 8 for its basis): $5 \times 2 = 10$; $10 \times 10 = 100$; $10 \times 100 = 1000$; $10 \times 2 = 20$; $10 \times 3 = 30$; $10 \times 9 = 90$; $7 \times 3 = 21$; $5 \times 9 = 45$; $9 \times 9 = 81$. Brackets were also expressed by $2 \times 2 + 1 = 5$; $2 \times [2 + 1] = 6$, and by two other messages of the same kind; the symbol for each bracket being a "line." The whole of this multiplication message occupied 16 minutes.

Division was then reached, by which the symbol which corresponds to our "decimal" point was established, and the meaning of "&c." was confirmed. The message is of this form: 6 (*divided by*) $3 = 2$; 12 (*divided by*) $4 = 3$. Then, 5 (*divided by*) $2 = 2{\cdot}5$; 7 (*divided by*) $4 = 1{\cdot}75$; 10 (*divided by*) $3 = 3{\cdot}333$, &c.

The whole of the division message occupied 15 minutes. Consequently the entire time spent thus far in actual signalling was 49 minutes. Adding about 10 minutes for intervening pauses, and another 15 for a long . . . pause at the close, this portion of the communication occupied one hour and a quarter. The records of the previous night agreed in form with these, but the examples chosen for the arithmetical operations differed. A superabundance of evidence is, therefore, already to hand to prove the justice of the interpretations.

It will be observed that the seven numerals, 1 to 7, the 0, and the equivalent to our decimal point, exactly use up the nine words of two letters each. It is, therefore, conceivable that 8 may have been taken by the Mars-folk as the basis of their notation in these signals, on this account alone, and not because it is the system in ordinary use by them. A clever little girl who has helped us much by her quick guesses, intreats me to add her own peculiar view, which is that the Mars-folk are nothing more than highly developed ants, who count up to 8 by their 6 limbs and 2 antennæ, as our forefathers counted up to 10 on their fingers. But enough of this.

There are a few apparent imperfections in the ensuing records, so I shall be glad of the experience of a third night, to revise thoroughly what has been already registered, and will, therefore, close my narrative for the present.

8. After the pause of fifteen minutes mentioned above, presumably to give time to the operators to readjust their instruments and to rest, the signals recommenced with the purpose of determining symbols to express the sun and the five principal planets. This was effected by three series of figures relating successively to mean distances from the sun, to their respective radii, and to times of rotation on their axes. The units of length were such that the earth's mean distance was taken as 100 in the first series, and her diameter as 100 in the second series; similarly her time of diurnal rotation was taken as 100 in the third series. Doubtless the Mars-folk thought that the values under those forms would suggest their meanings the more readily to terrestrial astronomers. I give the messages in a compressed form, thus :—*Sun* (*mean distance from*) *Sun* (equal) 0 ; *Venus* (*mean distance from*) *Sun* (equal) 72 ; *Earth* (*mean distance from*) *Sun* (equal) 100 ; *Mars*, 153 ; *Jupiter*, 520 ; *Saturn*, 954.

Similarly, as regards the radii of the several planets :—*Sun* (*radius of*), 11,164 ; *Venus*, 97 ; *Earth*, 100 ; *Mars*, 53 ; *Jupiter*, 1,127 ; *Saturn*, 1004.

Here, however, either " diameter " or " circumference " would suit the context, as well as " radius." The assumed interpretation is confirmed later on, where the word radius is determined through a different connection. Another table of a similar kind refers to the relative periods of revolution on their respective axes.

Very little time was occupied in deciphering the above, as our whole staff were simultaneously engaged upon the records, all of whom were more or less familiar with these sequences of figures. When once the interpretation had been suggested, its truth was quickly seen to be beyond doubt, it being incredible that any other series of values should exist for which the above sequences might be mistaken. This astronomical message occupied twenty-five minutes and was accompanied and followed by a total pause of ten more.

9. Let it not be supposed that the value of the last and of the present message is confined to their intrinsic interests, for they are intended to introduce a descriptive method of a most unexpected and far-reaching character.

The signals recommenced with the series of figures which is perhaps the most familiar of all to mathematicians and astronomers, namely that which expresses the relation of the circumference of a circle to its diameter, or to double its radius.

We always symbolise that relation by the Greek letter π, and usually symbolise the radius by r. The signals were—π (equal to) 3·141592, &c. (*circle*) (*perimeter of*) (equal to) 2 (multiplied into) π (multiplied into) r.

There cannot be a doubt as to the second pair of these signals meaning π and r and of the first pair meaning "circle" and "perimeter"; which is soon explained. In the first place, these signals are followed by (*circle*) (*area of*) (equal to) π (multiplied into) r (multiplied into r), which is a most familiar formula, and by determining both "circle" and "r," it establishes "perimeter" and "π." After this came a series of signals for establishing eight new words, which seeming at first sight to be little worth the trouble taken about them, are in reality important data. They are the names of the following regular polygons, as determined by their perimeters in one series and by their areas in another: namely, an equilateral triangle, a square, a pentagon, hexagon, octagon, dodecagon, and one with twenty-four sides. The nomenclature of the polygons is contrived to suggest the proper interpretations, by prefacing their names with the number that expresses the number of their respective sides.

The first series runs (3-gon) (perimeter) (equal to) 3; (4-gon) (perimeter) (equal to) 4, and so on. The second series is (3-gon) (area) (equal to) 4·33; (4-gon) (area) (equal to) 1·00; (5-gon) (area) (equal to) 1·72, and so on. The sequence of the first series is obvious; that of the second is fairly well known, otherwise it can be easily calculated. Of course the sides are in each case taken as equal to 1. The time occupied in the actual signalling of the two series was twenty-five minutes, or including short pauses in the middle and a longer one at the end, thirty-five minutes.

10. We now reach the threshold of the final and most marvellous stage, namely that of effective picture-writing in outlines by means of series of words of three letters. It will be shown how names of three letters are assigned to each of the 24 sides of a regular 24-gon, which are of course of the same length and are inclined to the same line (let us say to the north and south line) by successive increments of 15 degrees (the 360° into which we usually divide the circle, when divided by 24 being equal to 15°). Thus, the left-hand side of the 24-gon has a slope of 0°, or of 360°, whichever we please to call it; the adjacent side, proceeding upwards, has one of 30°; the next, one of 45°, and so on all round the compass. They would be the same in their directions as the so-called "rhumbs" of a mariner's compass, if sailors divided their cards into 24 and not into 32 "points." If we take every second side of the 24-gon, and bring them together, they form a 12-gon. If we take every third side, the result will be an octagon; similarly for the hexagon and equilateral triangle. The symbols for the 24 sides are, as mentioned already, words of three letters; now there are 27 such words: consequently 3 remain over; one of these was used for "-gon," and another is found to be employed for "picture-writing," because it precedes every communication of the kind and is accompanied by a register number, to admit, as we may suppose, of each message being hereafter identifiable. The message by which this information is conveyed is of the following form, in which, for the convenience of the reader, the directions of the several sides are given in degrees of arc of our scale, though the 24 letters, a, b, c, &c., up to x, would more closely represent the actual signals.

It began by (*picture formula*), followed by a short pause; then—

(*Picture formula*) (24-gon) (equal to) 0°, 15°, 45°, &c., to 345°
(*Picture formula*) (12-gon) (equal to) 0°, 45°, 90°, &c., to 315°,

and so on all through the series. We may look on the picture formulæ as expressing the directions of each consecutive stitch in a piece of embroidery, those stitches being all of equal length. There was some delay in puzzling out the above interpretation; it was first discovered by the young lady mentioned above, who is more successful than most of her companions in guessing charades and at such like games.

Further messages show that both the length of the stitch and its inclination may be specified more delicately by the help of decimals. Thus let j be the symbol for a stitch in any given direction, then $0{\cdot}5 \times j$ means a half-length stitch in the direction j. A series of 4 triangles were signalled to explain this, in which the angles corresponded exactly with certain of the rhumbs, while the sides had to be expressed with decimals. Similarly as to the decimal division of the direction between rhumbs; in the first instance the pentagon was described, and then a series of four triangles, in which the sides were integral and the angles decimal. Short stitches are useful where the contour makes a sharp turn; minuteness of direction is sometimes wanted for the long lines in diagrams, but never for the short lines. Decimal directions are distinguished by brackets, thus [$0{\cdot}3j$]. It will be recollected that the symbols for brackets, which are simply "lines," were determined during the multiplication message. The actual signalling of all the information described in this and the preceding letter occupied one hour and ten minutes, which was increased to an hour and a half by the pauses during its transmission and at its close.

11. A rapid retrospect may now be taken of what has been accomplished by less than two-and-a-half hours of actual signalling, together with pauses occupying a little less than one hour, making a total of three-and-a-half hours altogether. We have been made to completely understand the numerical notation of the Mars-folk, including their equivalent to our decimal point, and we have learnt the following twenty-nine words:—Area, brackets, circle, circumference, distance from, divided by, dodecagon, earth, equal to, etcetera, hexagon, Jupiter, Mars, minus, multiplied into, octagon, " ," pentagon, perimeter of, picture-formula, radius, rhumb, Saturn, square, sun, twelve-sided regular polygon, triangle, equilateral triangle, Venus. We have also learnt how to draw any triangle, and implicitly how to draw any polygon, regular or irregular, from a picture-formula.

We now proceed to the ordinary picture-formulæ, of which nine have been received in the six nights during which the signals have been recorded. The power of the method is easily seen by drawing any outline with dots at equal distances apart, and counting those dots. A dozen or fifteen are quite sufficient to indicate a figure, or a letter, or other simple object, and as each dot occupies a quarter of a minute to transmit, as many as 240 can be sent in an hour. A considerable assistance to ensuring the accuracy of the method is given by selecting convenient points of reference in the drawing, which we may call A, B, C, &c., and by giving the distance of each of them from one or more of the others. This divides the drawing into stages, any one of which may be faulty without prejudice to the rest. It also enables detached parts to be drawn, commencing at one of the letters as a point of departure and ending at another. The points of reference are signalled thus:—A (distance to) B $42j$; B (distance to) C $36d$, and so on. The sign for "distance to" was determined in the letter No. 8.

The first of the pictures selected for decipherment was headed by the odd phrase "(picture-formula) 0·5 (Saturn)." It proved to be a beautiful representation of *one half* of Saturn and his ring. The other half, being symmetrical, did not need to be signalled. Only 105 "stitches" were employed. Another picture headed "Earth" proved to be a view of the American continent. 52 stitches sufficed for South America; but 88 were used for North America on account of the indentations of its shores; moreover, 16 of these were fractional stitches. A very good map was given of the solar system at the present date, so far as concerns the positions of the five principal planets about the sun. I must not at present speak of the domestic and sociological drawings, of which a new one is received every night, and the question whether or no the Mars-folk are glorified ants must remain for a short time longer in abeyance.

It is needless to continue in the same strain. I should say that the elements of the art of drawing outlines from written formulæ that admit even of being telegraphed, was explained by me in a Friday Evening lecture, on the *Just Perceptible Difference*, at the Royal Institution in 1893. Many illustrations of the method were then exhibited, one of which appears in the printed report. A large drawing of a Greek head had been made and formularised, then the formula was translated into dots upon paper, on the same large scale; rings were painted round the dots, and, lastly, the original and the copy were reduced by a photo-process to three different sizes. These form the printed illustrations. There were 271 dots, or rather rings, in this very effective picture, which contained the contour of the face, the sweep of the hair, the eyelids, and eyebrows.

It would be easy to enlarge the above vocabulary. Thus water and the metals could be defined by their relative specific gravities and other physical properties; colours by diagrams of the prism and of the rainbow. Units of length and time have been already determined by the diameter of any given planet and the time of rotation on its axis; that of weight on the surface of any named planet could be determined also; and picture-writing would extend the list of named objects indefinitely. But substantives alone cannot form a language; the symbols for other parts of speech must be explained by pictures, those for the past, present, and future tenses by pictures of objects in motion.

It would be tedious, and is unnecessary to elaborate further, for it must be already evident to the reader that a small fraction of the care and thought bestowed, say, on the decipherment of hieroglyphics, would suffice to place the inhabitants of neighbouring stars in intelligible communication if they were both as far advanced in science and arts as the civilised nations of the earth at the present time. In short, that an efficient inter-stellar language admits of being established under those conditions, between stars that are sufficiently near together for signalling purposes.

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