RSVP ASAP

6 is an interesting number. Beside 6 itself, it has factors 1, 2, 3 and if you add these together you get back to the original number, 6. That doesn't work for too many numbers, so mathematicians call 6 a 'perfect' number. Being perfect, it obviously follows there can be only six planets.


The birth of a planetary system

As an argument, this remains as true, or false, today as when it was first stated, a time when only six planets were known. What's changed is not the philosophical argument (which has been quietly forgotten) but the scientific discovery that there are more than six planets. After 6, the next perfect number is 28 and then 496. Perfection is very rare among numbers - only thirty-seven perfect numbers are known. Rarer, it would appear, than entire planetary systems, some 88 of which have been discovered recently in our stellar neighbourhood.

A hundred years ago Simon Newcomb, a leading academic, published a book in which he calculated that flying machines were a physical impossibility and that the best alternative would be a carriage chained to teams of trained birds. Almost before the learned man's ink was dry, Orville and Wilbur Wright, with rather less academic pedigree, built and flew the world's first heavier-than-air flying machine. Still, scepticism about flying machines persisted. But then to this day, some people insist the earth is flat or that man did not set foot on the moon.

Several years before the outbreak of World War II the British government politely declined stolen secrets of the German cipher machine, Enigma. Even in possession of a complete Enigma, leading code-breakers had calculated that, without a knowledge of the daily machine settings, it would take hundreds of years and massive resources to decode even a single message. Until as late as July 1939, the British were completely unaware that three young Polish mathematicians, with virtually no resources, were breaking into the Enigma traffic almost on a daily basis.

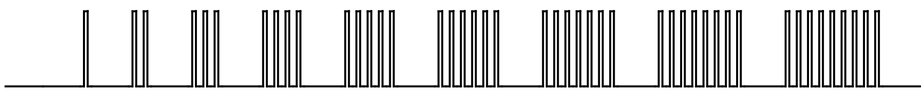
Sometimes, proving the impossible seems significantly harder than doing it.

In 1967 Jocelyn Burnell recorded an extra-terrestrial radio signal showing highly unnatural features. Very precisely timed radio pulses, not at all like the typical “wail and howl” signals generated by the sun, stars and planets, suggested to some, evidence of an extra-terrestrial intelligence. At first astronomers suspected signal interference from the burgeoning digital radio technology of the time. This possibility was eliminated by the discovery that the signal faded whenever the moon obstructed a particular point in the sky.

For a while the scientific world held its breath while observers and theorists feverishly scrambled to explain the signals in terms of extra-terrestrial messages or stellar-like objects operating at the limits of the known laws science. Eventually it was shown that such signals could be generated by highly collapsed stars which, though rare, are a natural product of stellar evolution. This view was confirmed when theorists calculated that the rate of rotation of such stars would have to decrease, causing the interval between radio pulses to increase. The slowing down has been subsequently confirmed by observations to a very high level of precision. Today these objects are known as pulsars.

Precisely timed radio pulses are rare in the universe, which is why huge scientific interest was aroused by the discovery of pulsars. The receipt of the following signal, repeated over and over again, would cause even greater scientific interest simply because its generation by natural sources would be so hard to explain scientifically. Cosmological objects simply do not increment up to a certain number and then start again. This is more the product of a digital phenomenon.

Figure 1.

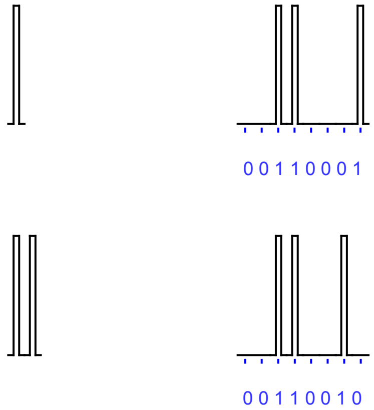


The reception of such an extra-terrestrial signal would be a startling event, yet its information content is not particularly profound. After the initial shock, we would be keen to learn of something a little more than a primitive allusion to the first nine counting numbers.

In exchange however, we might expect to have to work harder to decode the rest of the message. The reason is straight forward. The above method of transmitting the first nine counting numbers, while intuitively obvious and mesmerising, is a very inefficient method of communicating. The problem is simply that the length of the message increases in direct proportion to the size of the numbers. Even the Romans gave up after three, preferring to use a simple code for larger numbers:

I II III IV V VI VII VIII IX

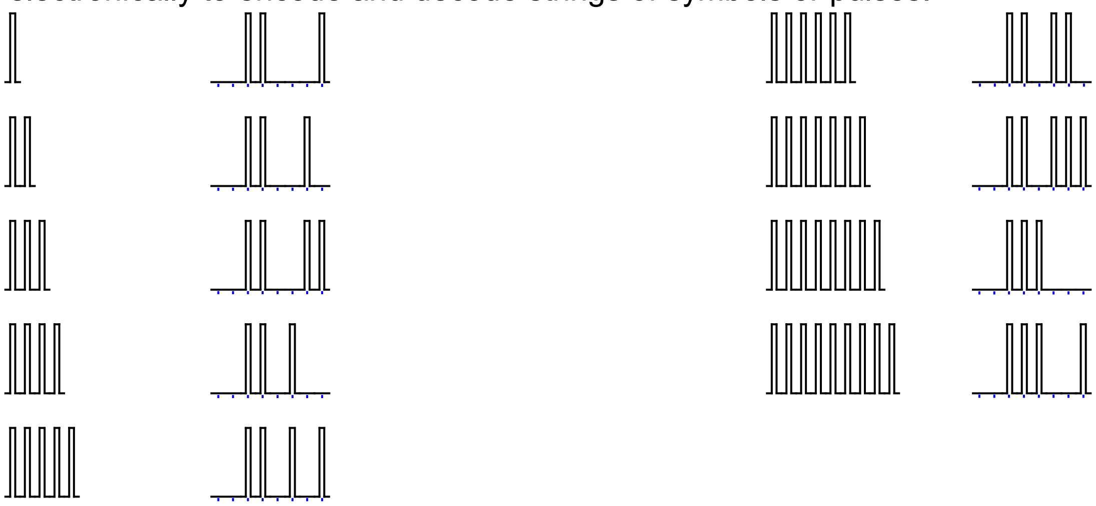
We, in turn, should expect a much more efficient and systematic method of encoding information. Whether as senders or receivers then, we need to think about the coding and decoding of information before we can proceed with the rest of the message.



Modern life is totally dependent on binary coding, enabling everyday tasks such as using a mobile, setting a timer or typing a letter. Actually, pressing the “1” button on a keypad, electronically generates the binary code 00110001, a form more easily handled by digital electronic devices (1 = pulse, 0 = no pulse). A “2” generates the pulse pattern 00110010.

Quite why anyone might choose to represent 1 by 00110001 is no longer very obvious. The code was first developed in the 1960’s to allow geographically distant computers to exchange textual data, A = 01000001, a = 10100001, etc. In addition, the code caters for various unprinted characters such as line feed, carriage return, page feed, end of message, etc. In the end, it is just a code and any other code is perfectly usable. However, having devised such a code, it makes sense for everyone to stick with it (just as, having decided on which side of the road to drive - one might think - it makes sense to drive on that side).

This particular code, known as ASCII (American Standard Code for Information Interchange) maps each of 256 (= 2^8) characters to a distinct 8 bit binary number or pulse pattern. ASCII represents an expanded alphabet - fifty-two upper and lower case letters, ten digits 0 to 9, the space character, punctuation and various other symbols, all assembled into a 256 character alphabet (see appendix). Having agreed a binary code, it is very simple electronically to encode and decode strings of symbols or pulses.



By transmitting the above signals repeatedly we might convince ourselves, and any interested receiver, that we are supplying our codes for the digits 1 to

9. Whatever symbols our receivers use to denote the digits 1 to 9, is their business. We are informing them of our symbols and we leave it to them to compile their own translation.

For technical reasons, our entire message has to be transmitted as a one dimensional sequence of binary pulses. However, in order to avoid the mind-numbing effect on the terrestrial reader of reading and writing a message solely in terms of binary pulses, I will assume the translation into binary pulses to be transparent, of no further interest to the reader and focus on the process of carefully introducing each new symbol and its use. For example, from this point on, where we have identified the codes for the first nine integers, I will refer to them simply by:

1 2 3 4 5 6 7 8 9

and understand that on transmission they are always translated into the unique groups of binary pulses defined by the ASCII table.

For readability, symbols which have been introduced in this way are printed in **bold** and described as “acquired”. Thus, as a symbol is acquired, it turns **bold**. The broad aim is to transmit predominantly **bold** examples, with only one or two new (non-bold) symbols to be decoded from context.

For example, suppose we transmit (binary pulse representations of) the following:

2 $ **1** @ **3**   **1** $ **1** @ **2**   **3** $ **4** @ **7**   **5** $ **2** @ **7**   **2** $ **2** @ **4**   **2** $ **6** @ **8**

A receiver would not need many examples to guess that the unknown symbols $ and @ coded for our + and = respectively. We could transmit many more such examples to confirm these guesses. More convincing perhaps, would be to send extended uses of these symbols, such as

2 $ **1** $ **3** @ **6**   **2** $ **2** $ **1** $ **2** @ **7**   **2** $ **1** $ **4** @ **2** $ **2** $ **1** $ **2** @ **7**

This “guess and confirm” process for helping a receiver decode our symbols is a highly efficient strategy (and a powerful technique in terrestrial code breaking).

Here I have used the symbols $ and @ merely to demonstrate the strategy to the terrestrial reader. In the actual message we would simply transmit the binary representations of + and = (00101011 and 00111101) and leave it to our receivers to decode their meaning and translate into their equivalents.

In a similar way, examples such as

2 + # **= 2**   # **+ 5 = 5**   **4 +** # **= 4**   **3 +** # **=** # **+ 3 +** # **= 3**

should quickly convince a receiver that the new symbol codes for our zero symbol 0 (00110000), so our receivers would append this new symbol and its translation to their dictionary. Meanwhile as senders we would add **0** to our table of acquired symbols:

0 1 2 3 4 5 6 7 8 9 + =

Notice that the space symbol " " (00010000), which I have used indiscriminately for readability, needs a formal introduction at some stage. For now we simply note that this is one symbol whose use we can convey by incrementing the time intervals between groups of pulses.

This is a good point to transmit the following:

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17
18 19 20 21 22 23 24 25 26 27 28 29 30 31 32
33 34 35 36 37 38 39 40 … 93 94 95 96 97 98
99 100 101 102 103 104 105 106 107 108 109 110
111 112 113 114 115 116 117 118 119 120 121 …
998 999 1000 1001 1002 …

illustrating our use of place value (base 10) to represent larger numbers. Technically, we need to arrange that groups of digits are separated by longer time intervals than the constituent digits, as indicated. This is also a good opportunity to introduce **…** the "and so on" symbol group (00011101 00011101 00011101)

Our number system can be usefully confirmed by many examples such as

8 + 4 = 12 6 + 5 = 11 7 + 6 = 13 9 + 8 = 17 12 + 92 = 104

We could also transmit ten pulses followed by the binary groups **1 0**, etc. for further confirmation.

We now introduce negative numbers and, in the process, reintroduce and sharpen our representation of positive numbers. We transmit the sequence:

… $^{-}8$ $^{-}7$ $^{-}6$ $^{-}5$ $^{-}4$ $^{-}3$ $^{-}2$ $^{-}1$ 0 $^{+}1$ $^{+}2$ $^{+}3$ $^{+}4$ $^{+}5$ $^{+}6$ $^{+}7$ $^{+}8$ **…**

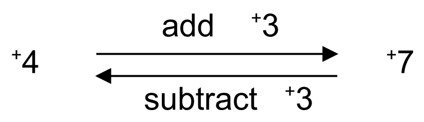
The two new superscripts are coded by two new ASCII codes distinct from anything else so far transmitted. We are careful to use entirely new symbols to flag positive and negative numbers to avoid any ambiguity with the operations add and subtract, a courtesy - to our shame - we do not extend to our school children, generations of whom we continue to baffle with our sloppy use of the one symbol + for two distinct meanings. The new symbols serve to flag two varieties of numbers, which still increment away from zero, but now in opposite directions.

While the sequence by itself should be sufficient to identify the new symbols, as always, we supply copious examples:

$^{+}2 + {}^{+}3 = {}^{+}5$ $^{+}4 + {}^{-}2 = {}^{+}2$ $^{-}3 + {}^{+}2 = {}^{-}1$ $^{-}7 + {}^{-}15 = {}^{-}22$

Earlier examples identified the effect of the add operator acting on a domain of purely positive numbers. Its effect there was to sum the net number of increments from zero, all steps being in the same direction. The introduction of negative numbers results in two directions from zero. The add operator is still seen to sum the net number of increments from zero, but now negative numbers count as steps in the opposite direction. Clearly, earlier examples, while technically correct, illuminated only a limited domain of action of the add operator.

Having established the general “guess and confirm” method for introducing new symbols, it is time to increase the instruction rate. We now introduce subtract as the operator that inverts the add operation. If starting with $^{+}4$, the action of the add operator and $^{+}3$ results in $^{+}7$, then starting with $^{+}7$, the action of the subtract operator and $^{+}3$ is to return to the original $^{+}4$:



We send examples of the form:

$^{+}4 + {}^{+}3 = {}^{+}7$ $^{+}7 - {}^{+}3 = {}^{+}4$

$^{+}4 + {}^{-}3 = {}^{+}1$ $^{+}1 - {}^{-}3 = {}^{+}4$

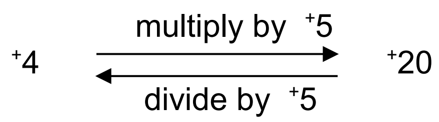
$^{-}4 + {}^{+}12 = {}^{+}8$ $^{+}8 - {}^{+}12 = {}^{-}4$

to identify the new subtract symbol.

Similarly, we introduce the multiplication operator through examples such as

$^{+}4 * {}^{+}5 = {}^{+}20$ $^{+}3 * {}^{-}21 = {}^{-}63$ $^{-}3 * {}^{+}6 = {}^{-}18$ $^{-}12 * {}^{-}45 = {}^{+}540$

The division operator is the operator that inverts the multiplication operation:



and send examples such as

$^{+}4 * {}^{+}5 = {}^{+}20$ $^{+}20 / {}^{+}5 = {}^{+}4$

$^{-}3 * {}^{+}6 = {}^{-}18$ $^{-}18 / {}^{+}6 = {}^{-}3$

$^{-}12 * {}^{-}45 = {}^{+}540$ $^{+}540 / {}^{-}45 = {}^{-}12$

While we do not have a problem sending numerous examples of multiplication, we would soon run into difficulties with division. For example, we have not described our number representation sufficiently to transmit the result of $^{+}$**5** / $^{+}$**2**, not yet having introduced the decimal point notation.

Suppose we send examples such as:

2 * 100 + 3 * 10 + 6 * 1 + 5 / 10 + 7 / 100 = 236.57

4 * 100 + 0 * 10 + 1 * 1 + 0 / 10 + 7 / 100 = 401.07

0 * 100 + 3 * 10 + 9 * 1 + 2 / 10 + 8 / 100 = 39.28

6 * 100 + 8 * 10 + 0 * 1 + 5 / 10 + 0 / 100 = 680.5

where the only new symbol is "**.**" (00101101) embedded in the final value of each example. These examples demonstrate the use of our decimal point notation. They also warn of our habit of dropping leading and trailing zeros.

Let's recall our purpose is not an exhaustive instruction course in elementary arithmetic, but merely to supply sufficient examples to allow receivers to acquire our symbols and their use.

This would be a good time to introduce the symbols ≠(not equal to), ≈ (approximately equal to), <(less than), >(greater than), ≤ (less than or equal to), ≥(greater than or equal to), for which the reader will have no trouble constructing suitable examples.

We can introduce the exponent operator through examples like:

3^4 = 81 16^0.5 = 4 10^ -3 = 0.001 2^0.5 = 1.4142135623730950488…

Summarising, we have introduced positive, zero and negative numbers, the operations of add, subtract, multiply, divide and exponents, the comparing symbols = ≠ ≈ etc. and the decimal point number system. Now would be a convenient time to summarise progress in an end of chapter exercise (with answers of course), and introduce a few interesting numbers.

We might for example send a few thousand digits beginning

pi **= 3.141592653589793238462643…**
e **= 2.718281828459045235360287….**
gamma **= 0.577215664901532860606512…**

the decimal approximations of three mathematically significant constants we know as π, e, and γ. Later, we will be able to provide definitions and methods to calculate these to any desired accuracy.

We might also take this opportunity to introduce the useful brackets notation:

(3 + 5) = 8   4 * 8 = 32   4 * (3+5) = 4 * 3 + 4 * 5

4(3+5) = 4 * 3 + 4 * 5

The last example also exposes our habit of dropping the multiplication symbol where possible. The above examples could be usefully summarised by

a*(b + c) = a*b +a*c   a(b+c) = ab + ac

a general statement of the fundamental distributive law of arithmetic. In fact, this might be a good time to collect together and present as a whole all the fundamental laws of arithmetic.

Suppose now we transmit the following examples:

3 + x = 7   x = 4

8 - x = 6   x = 2

3 * x = 54   x = 18

19334.52 🕑x = 749.4   x = 25.8

This time we actually transmit the ASCII code for the symbol x (01111000). These examples clearly demonstrate the manipulation of symbols for the purpose of evaluating an unknown, a basic use of algebra.

We can identify a summation notation and various standard results in series via examples of the form:

S(r=1,10; r) = 1 + 2 + 3 + 4 + 5 + 6 + 7 + 8 + 9 + 10 = 55

S(r=1,n; r) = 1 + 2 + 3 + … + (n-2) + (n-1) + n = n(n+1)/2

S(r=1,n; r^2) = 1^2 + 2^2 + 3^2 + ….+ (n-2)^2 + (n-1)^2 + n^2 = n(n+1)(2n+1) /6

S(r=1,n; r^3) = 1^3 + 2^3 + 3^3 + ….+ (n-2)^3 + (n-1)^3 + n^3 = (n(n+1)/2)^2

Here is a suitable time to make good our promise to define some mathematically useful notations and constants:

n! = n*(n-1)*(n-2)*(n-3)…*5*4*3*2*1

pi / 2 = (2/1) * (2/3) * (4/3) * (4/5) * (6/5) * (6/7) …

e = 1 + 1/1! + 1/2! + 1/3! + 1/4! …

By now, where we have introduced some forty symbols, it seems clear that we can continue to introduce each new symbol of mathematics in terms of previously acquired symbols. Further examples might introduce particular and general forms of the quadratic, cubic and quartic equations and their solutions, leading onto complex numbers.

We can identify the differentiation operator D and its inverse, the integration operator I, by sending a list of standard results. This could lead onto a table of physically significant differential equations and their solutions and allows us to introduce exponential, logarithmic, trigonometric, hyperbolic, hypergeometric functions and so on.

Throughout all earlier examples we could, if we wish, associate with each new symbol, a string of unexplained symbols. For example to the acquired symbol **+** we could associate the string “add” (01100001 01100100 01100100).

Or we might prefer periodically to collect all newly acquired symbols together with their binary codes into a handy reference table and make the word association at that moment. Effectively we are starting a database (multi-level dictionary), each record of which refers to a particular symbol, each field of each record storing different kinds of information about that symbol.

Symbol	Code	Word	Substitute	Sound	Image	Video
+	00101011	add	plus	100111…		
=	00111101	equals	is equal to	011101…		
0	00110000	zero	nought	011011…		

For the moment we strive for simplicity, but later we might extend the number of fields per record. For example, we might append additional fields for

- substitutes (“plus” is sometimes substituted for the word “add”)
- sound (the string “add” has an associated, digitally encodable, sound)
- pictures (words may have an associated image)
- video (an ordered sequence of incrementally evolving pictures)

This would be a good time to start the database. The point is that sooner or later we need to move onto other fields of interest, such as the sciences and arts, for which we require more extensive vocabularies. Identifying associated words, their pronunciation and images now is a natural progression and one which eventually helps to accelerate the learning process.

Let’s make a start with a mathematical object and its associated image. Some mathematical equations are easy to associate with a simple image. For example the equation $x^2 + y^2 = 100$ associates quite easily with a circle. Consider the following message:

23 * 23 = 529

00000000000100000000000000000001000000010000000000000100000000000100000000010000000000000000010000
0001000000000000000100000010000000000000000000001000010000000000000000000010001000000000000000000010
0100000000000000000000100100000000000000000000010010000000000000000000001001000000000000000000000010
0100000000000000000000100100000000000000000000010010000000000000000000001000100000000000000000000100
0010000000000000000000100000100000000000000000100000001000000000000000100000000010000000000000100000
000000010000000100000000000000000000100000000000000000000000000000000

pi = 3.14159265358979323846264 3…

2*pi*r

pi*r^2

x^2 + y^2 = 10^2

The header statement recalls that 529 is equal to 23 * 23 and (it turns out) there are 529 subsequent digits, all 1 or 0. If this is not sufficient a clue, we note that 23 is a prime number, so there is also only one way to arrange 529 digits in a simple regular manner, namely as a 23 by 23 square. In fact, almost any arrangement results in “ghost” circles, a pattern screaming out for a readjustment of the “horizontal hold” value to 23. Finally, as confirmatory clues, each of the remaining statements refers in some way to a circle. Sooner or later, our receivers will arrange the digits into a 23 * 23 square.

0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Then, the “header information” will be seen as supplying the grid dimensions. 1 codes for (say) a black blob, 0 codes for (say) a white blob, or any other distinguishable pair of pixels. Accompanying information provides data describing the image, or data described by the image, or a mix of both.

Having demonstrated and further refined the method via a sequence of small simple images, it is then straight forward to give notice of increasing the parameters of the technique to more visually rewarding resolutions. For example, increasing the 529 digits to the equivalent of about 200,000 allows us to send the accompanying evocative image (available in full colour from nssdc.gsfc.nasa.gov/photo_gallery)

It is interesting to recall that some forty years ago, schoolboys from Manchester Grammar School intercepted, identified and decoded just such a radio signal from space. They were able to supply the first close up pictures of our moon, ahead, and much to the annoyance of, the Russian owners of the space craft transmitting the signals.

With words and images, we can rapidly introduce geometry and trigonometry and further expand the acquired vocabulary. Right angled triangles, Pythagoras' Theorem, Pythagorean Triples, Angles, Trigonometric functions, and even Fermat's Last Theorem are all accessible. For example,

if ($x \in Z$ and $y \in Z$ and $z \in Z$ and $n \in Z$ and $n>2$) then $x^n + y^n \neq z^n$

… is a complete statement of Fermat's Last Theorem. We would have had to previously introduce: if, then, and, $\in$(belongs to), and Z (the set of all positive integers), but by now all that's fairly routine. A statement of Fermat's Last Theorem is one thing however. We would no doubt wish to postpone its proof for a while. That proof, as Sherlock Holmes might say, is a two pipe problem.

Other proofs though, are more accessible. For example, the proof that the square root of 2 cannot be equal to the ratio of any two whole numbers, the proof of the existence of an infinite number of prime numbers, Pythagoras' theorem, etc. The transmission of an ordered sequence of logical statements comprising a mathematical proof is an important threshold in our message construction. We are starting to write joined-up maths.

By now we have assembled a large body of examples and terminology, greatly expanded our database of associated words and begun to write mathematical prose. Having used the fact that all of mathematics can be derived from counting, we now go on to use the ability of mathematics to describe "unreasonably well" the observable universe.

The first task must be to establish some fundamental units of measurement in terms of which all subsequent data is referenced. While here on Earth we seem prepared to operate under unholy mixtures of units (eg. meters, miles and knots; litres, imperial gallons and US gallons, and let's not even mention currencies), resulting in confusion and disasters on a depressing scale, we cannot afford such ambiguity in our initial message. We first introduce an identifiable unit of mass and, as usual, leave our receivers to translate into their preferred units.

We note that wherever we look in the universe, and for billions of years into the past, we see the same fundamental components of matter behaving in exactly the same ways – same mass, same periods of oscillation, same spectral lines of radiation. A few fundamental particles interacting with each other under a few mathematically specified laws of interaction. The quantum nature of the universe allows us to identify universally significant phenomena with simple numerical values. A table of such numbers therefore serves to characterise matter in a very distinctive and universally recognizable manner.

For example, 1.0072766 1.0086652 0.0005486 are the masses of the proton, neutron and electron respectively, three of the most ubiquitous particles in the universe. In fact the proton to electron mass ratio, 1.0072766 / 0.0005486 = 1836.086, is one of the most recognizable numbers in particle physics. So, if we transmit

proton mass **= 1.0072766**
neutron mass **= 1.0086652**
electron mass **= 0.0005486**

this might be sufficient for the alert receiver to decode, not only the fundamental unit of mass in question, but also the word “mass” (since it appears in each reference) and, as everything else is now known, our labels proton, neutron and electron.

Whatever, the following table of numbers would decide the matter and confirm any initial guesswork:

1	**0**	**1**	**1.0078252**	**1.0078250**	**0.0000002**	H
2	**2**	**2**	**4.0329808**	**4.0026030**	**0.0303778**	He
3	**4**	**3**	**7.0581364**	**7.0160050**	**0.0421314**	Li
4	**5**	**4**	**9.0746268**	**9.0121830**	**0.0624438**	Be
5	**6**	**5**	**11.0911172**	**11.0093050**	**0.0818122**	B
6	**6**	**6**	**12.0989424**	**12.0000000**	**0.0989424**	C
7	**7**	**7**	**14.1154328**	**14.0030740**	**0.1123588**	N
8	**8**	**8**	**16.1319232**	**15.9949150**	**0.1370082**	O
9	**10**	**9**	**19.1570788**	**18.9984030**	**0.1586758**	F
10	**10**	**10**	**20.1649040**	**19.9924390**	**0.1724650**	Ne
...						
55	**78**	**55**	**134.1062718**	**132.9054330**	**1.2008388**	Cs
...						
92	**146**	**92**	**239.9850379**	**238.0507860**	**1.9342519**	U

It takes no great knowledge of atoms to guess, and subsequently check, that the first three whole numbers specify the number of protons, neutrons and electrons, respectively, in some ninety-two chemically distinct and universally available varieties of atoms.

The significance of the numbers 1.0072766 1.0086652 0.0005486, if not obvious before, would now be apparent from the fourth number, identifiable as the mathematical sum of the atom’s constituent masses:

1 * 1.0072766 + 0 * 1.0086652 + 1 * 0.0005486 = 1.0078252

55 * 1.0072766 + 78 * 1.0086652 + 55 * 0.0005486 = 134.106718

92 * 1.0072766 + 146 * 1.0086652 + 92 * 0.0005486 = 239.9850379

The table identifies our unit of mass: that value for which the mass of the carbon atom (with 6 protons, 6 neutrons, 6 electrons) takes on the exact value 12. The fifth number, which is always slightly smaller than the fourth, is recognizable as the experimentally observed mass of the atom, all stable atoms in nature being observed to have a characteristically smaller mass than the mathematical sum of their constituent parts.

The sixth number, the difference of the previous two, and known to us as the mass defect, is a very significant physical quantity being a measure of the energy entombed in the atom. The seventh entry is our symbol for this chemical species of atom, which we supply to associate all future references.

We now identify a fundamental unit of time. All atoms have built in clocks and identical atoms tick (electronically oscillate) at identical rates. For example, a an atom of Cesium, in common with all other Cesium atoms in the universe in the same electronic configuration, undergoes 9,162,631,770 electronic oscillations per second. We adopt the time taken for one such oscillation as our fundamental unit of time, in terms of which all other measurements of time can be expressed.

We communicate this to our receivers by another data table, each line of which identifies a particular atomic transition together with its observed number of oscillations per unit time, and for which the Caesium entry records 1.000000. We supply these simple and universally recognizable numbers for a convincingly large number of atomic transitions. Effectively, we are transmitting a table of discrete energy levels of atoms, a numerical rainbow of the elements.

Given now the universal nature and constancy of the speed of light throughout the universe, we can define a fundamental unit of length as the distance travelled by light in one fundamental unit of time. Again, this identification is most easily made through a table listing the lengths (in the new units) of universally available systems, for example chemical bond lengths within various molecules.

Having introduced some fundamental units, the chemical elements and their symbols, we can extend this knowledge to include their associated names, pronunciation, images, numerically identifiable physical and chemical properties (eg. mass density, electrical conductance, Young's Modulus) etc., amassing a large body of associated vocabulary in the process.

We can then go on to perform an entirely analogous, but more extensive, review of the chemical and biochemical compounds, H_2, O_2, CO_2, HCl, NH_3, H_2O, OCS, CH_4, CH_3CH_2OH, …fatty acids, amino acids, sugars, ADP, ATP…, complete with names, physical and chemical properties (eg. bond lengths, angles, shapes, electron orbitals, molecular chains, rings, helixes, modes of vibration and rotation, reaction sequences etc). We can specify and chart the entire map of biochemical pathways used by living forms on this planet.

If all this appears a little demanding, technically, we should recall that modern radio technology is capable of transmitting some 10^9 pulses per second, sufficient to send all twelve volumes of the Oxford English Dictionary in a few seconds.

It is clear by this stage we will have acquired a large vocabulary and a level of exposition comparable to the average technical reference work, maybe not flowing and metered prose, but nevertheless a clear connected stream of information and underlying concepts. In terms of vocabulary and grammar, we have reached a reading age of about seven, although via a completely different route to that of our early years.

It probably doesn't serve our purpose much longer to continue the painstaking translation of our knowledge in this "guess and confirm" manner. Now we simply start transmitting entire standard works of reference and let our receivers perform the necessary translation, cross-referencing and associational mappings of our language.

After all, this is not too different to the way we, here on earth, pass on information to successive generations: a starter vocabulary of a few words, a graded set of books, dictionaries and encyclopaedias and subsequent referral to standard works for more detailed inquiries. We see at work the same process of learning by association, except, instead of pointing to an object and saying, for example

mummy   teddy   sweetie   sunny   stars

we point to objects available to our receivers and say

3   add   proton   oscillate   star

Though we set out from different places the destination is the same.

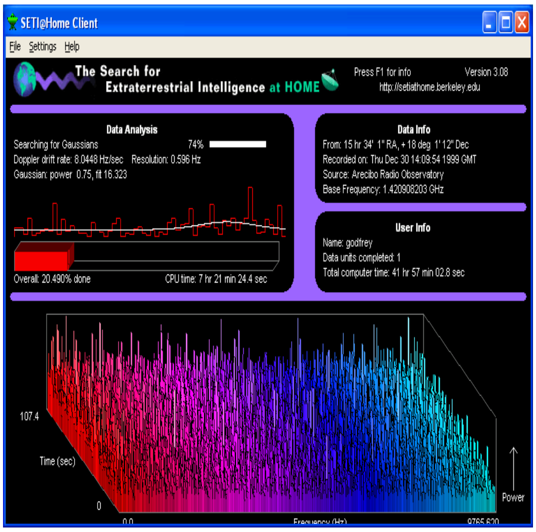
The size of the starter vocabulary required before dictionaries can be used to increase that vocabulary, is a tricky question. An informal poll among staff here puts estimates between 20 and 2000 with a mode around 800. With entire dictionaries now available on CD, it might be possible for the enthusiastic computer buff to check this using a clever bit of programming. Let's now put the finishing touches to our menu of suggested reading.

The choice of starters and main course, described in some detail above, result from the necessity to establish a starter vocabulary by referring to objects and processes immediately available to our receivers. That done, we can now move on to more interesting fare. As Desert, may we suggest a selection from our literature? Maybe here we do hesitate a little - should we alert our guests to the wickedly delicious richness of human expression arising from our continued use of several thousand different languages? Maybe not. Perhaps we simply download a library of suggested reading and dictionaries, and leave them to it.

After that, hopefully replete, perhaps they might care to relax with a little of our music, art and entertainments? Anyway, whatever we send we would, surely, append an RSVP ASAP.

Technically, we should expect some clever decodable tricks (such as fractal compression) to hide away huge amounts of data until required.

But more important than what we would send and how, is the insight gained into what, one day, we might receive. If we have not considered this we might not recognize what is sent when it does arrive… if it hasn't already.



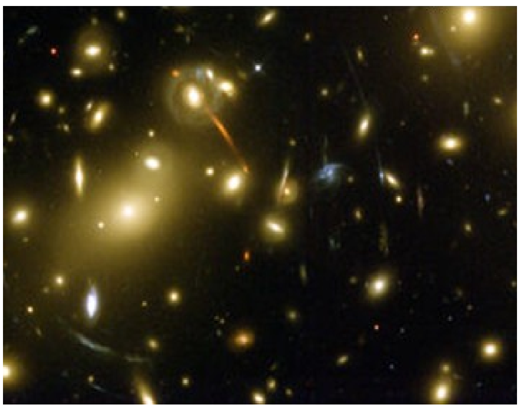
If you wish to participate in SETI (Search for Extra-terrestrial Intelligence) you can now download a simple screen saver from the SETI website
http://setiathome.ssl.berkeley.edu

Rather than bored goldfish drifting across your screen, your computer slack time can be used to analyse the latest signals received by the Arecibo radio telescope, as part of the world-wide SETI-at-home project.

Mankind's perceived role in the universe has suffered a sad decline over the centuries. The ancients would have us centre-stage, living on a flat earth, with the sun and moon hauled daily in chariots across the sky for our entertainment.

Copernicus and Newton relegated the Earth to one of six rather minor bodies moving in simple mathematical homage to the Sun. Since Newton, astronomers have progressively relocated the Sun to just one fairly unremarkable star among billions, far from the centre of an unremarkable galaxy, itself just one galaxy among billions. Very recently, many other planetary systems, both established and in the very process of formation, have been discovered in orbit around nearby stars.

Observations of the early universe show an almost unbelievable uniformity in initial physical conditions, with variations across the observable universe of less than one millionth of a degree temperature difference throughout the early phases.



The particles of our bodies and our world are the same particles, occur with the same relative abundances and obey the same laws of interaction, as in stars of the most distant galaxies.

Many of the biochemical precursors for life on Earth have been synthesised in the laboratory and detected in vast quantities in interstellar space. All life forms found on Earth use the same molecular code to record, maintain and improve their chemical blueprint from one generation to the next. A large fraction of human DNA is identical to that of many other species.

The discovery of intelligent life elsewhere in the universe will come as just one more reality check to mankind's perceived role in the scheme of things.

The day the digits come will be a defining moment for everyone on Earth. Nothing will ever seem quite the same way again. To know another intelligent life form exists elsewhere in the universe will change our perspective forever. We ought to start thinking about the implications.

Appendix – ASCII table (first 128 codes)

Dec	Binary	Sym	Dec	Binary	Sym	Dec	Binary	Sym	Dec	Binary	Sym
0	00000000	NUL	32	00100000	SP	64	01000000	@	96	01100000	`
1	00000001	SOH	33	00100001	!	65	01000001	A	97	01100001	a
2	00000010	STX	34	00100010	"	66	01000010	B	98	01100010	b
3	00000011	ETX	35	00100011	#	67	01000011	C	99	01100011	c
4	00000100	EOT	36	00100100	$	68	01000100	D	100	01100100	d
5	00000101	ENQ	37	00100101	%	69	01000101	E	101	01100101	e
6	00000110	ACK	38	00100110	&	70	01000110	F	102	01100110	f
7	00000111	BEL	39	00100111	'	71	01000111	G	103	01100111	g
8	00001000	BS	40	00101000	(	72	01001000	H	104	01101000	h
9	00001001	HT	41	00101001	)	73	01001001	I	105	01101001	i
10	00001010	LF	42	00101010	*	74	01001010	J	106	01101010	j
11	00001011	VT	43	00101011	+	75	01001011	K	107	01101011	k
12	00001100	FF	44	00101100	,	76	01001100	L	108	01101100	l
13	00001101	CR	45	00101101	-	77	01001101	M	109	01101101	m
14	00001110	SOH	46	00101110	.	78	01001110	N	110	01101110	n
15	00001111	SI	47	00101111	/	79	01001111	O	111	01101111	o
16	00010000	DLE	48	00110000	0	80	01010000	P	112	01110000	p
17	00010001	DC1	49	00110001	1	81	01010001	Q	113	01110001	q
18	00010010	DC2	50	00110010	2	82	01010010	R	114	01110010	r
19	00010011	DC3	51	00110011	3	83	01010011	S	115	01110011	s
20	00010100	DC4	52	00110100	4	84	01010100	T	116	01110100	t
21	00010101	NAK	53	00110101	5	85	01010101	U	117	01110101	u
22	00010110	SYN	54	00110110	6	86	01010110	V	118	01110110	v
23	00010111	ETB	55	00110111	7	87	01010111	W	119	01110111	w
24	00011000	CAN	56	00111000	8	88	01011000	X	120	01111000	x
25	00011001	EM	57	00111001	9	89	01011001	Y	121	01111001	y
26	00011010	SUB	58	00111010	:	90	01011010	Z	122	01111010	z
27	00011011	ESC	59	00111011	;	91	01011011	[	123	01111011	{
28	00011100	FS	60	00111100	<	92	01011100	\	124	01111100	|
29	00011101	GS	61	00111101	=	93	01011101	]	125	01111101	}
30	00011110	RS	62	00111110	>	94	01011110	^	126	01111110	~
31	00011111	US	63	00111111	?	95	01011111	_	127	01111111	DEL