The Evpatoria Messages

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ABSTRACT

In 1999, an international team, led by an American private interest, had been assembled with a single goal : the broadcast a message to the stars. The preamble as been written by the authors based on some notions of information theory and on anti cryptography. This message was later broadcasted from a Russian Deep-Space Radar installation in Ukraine. A similar messages was broadcasted 4 years later.

KEYWORDS

active-seti, message construction, Evpatoria

BACKGROUND

The authors are Canadian scientists who were involved in the design of both Cosmic Calls, which take place on May 24th, 1999 and on June 6th, 2003. Those were the third and fourth radio messages ever sent to an eventual extra-terrestrial civilisation. The first one has been carried by Frank Drake from the Arecibo radar in 1974 and the second by Jean-Marc Philippe from Nançay in 1987.

INTRODUCTION

Trying to communicate with an extra-terrestrial civilisation is a daunting task by any standard. Not only distances are colossal, but also we don't know who and where is our correspondent. There is not much information about how to communicate with him either. Technological limitations dictate the use of a radio transmission as the best medium of communication. Radar transmitters of Arecibo and Goldstone would have been very good for this project, but they were unavailable. Fortunately, after a long search, we discovered a Russian planetary radar, which was up to the task and open for business. The Evpatoria radar combines a 70-m antenna with a 150-kW transmitter. The characteristics of the Ukrainian based system fixed many parameters of the message. The wavelength was fixed 6 cm, far from the mythical 21 cm but still in the interstellar telecommunication window (between 1 and 10 GHz).

ERROR CORRECTION SCHEME

Numerous interstellar sources of noise exist and a radio transmission (depending on the carrier wavelength) will be surely affected by it. It is difficult to prevent the signal degradation. However, some solutions are possible to maintain the level of information.

The message itself (i.e. the content) must be written with a high redundancy. The information must be repeated through the entire message. Some concepts are even introduced using different approaches.

A communication system has a maximum error-free channel capacity[1] given by

$$C = W \log_2(1+\frac{S}{N})$$

where W is the bandwidth, S the signal power and N the noise power.

Obviously, wider the bandwidth more efficient is the communication. This leaded some authors to consider that advanced civilizations may use wide band signal to communicate with us[2]. Unfortunately, such wideband signal would be nearly impossible to differentiate from noise. Therefore, narrow band signal is expected at least to establish the first contact[3,4].

The other way to increase the communication channel efficiency is to reduce the signal to noise ratio (S/N). However, lowering the signal to noise ratio also increases the bit error rate. At very low signal to noise ratio, the message can be totally undecipherable. And beyond the simple repetition of the message ad infinitum[5], there is other ways of fighting the noise. In particular, error-correcting schemes could be embedded in the message[6].

The problem of noise resistance can be divided into two subjects: the container (i.e. carrier wave and the format) and the content (i.e. the information it-self).

THE CREATION OF THE ALPHABET

A simple approach when using a bitstream type of communication channel is to send a 1-D message. Typically made from a series of 0 and 1's. One can imagine the ASCII code or the MORSE code as example.

This fashion of sending information is quite useful and optimized for the bandwidth. However, it requires a protocol (i.e. check sums, parity) to ensure a high signal-to-noise ratio and a good understanding of the message.

Furthermore, the sending and the receiver must agree on the specific on that protocol else no information can be transmitted between them,

There is an alternative to the 1-D simple bitstream approach and it is the use of a 2-D technique (i.e. images). It is a more robust way of communication but requires some preparation (i.e. the need of a format) to ensure that the receiver will be able to understand the information.

Images are sent via their decomposition in lines and then through a bitstream. Again the problem of protocol is raised. However, the authors propose a solution to eliminate the need of a protocol when sending images. This will be discussed in a later section.

An image, as a carrier of information, provides us with the potential to send more information while using the bandwidth of a bitstream. The image is constituted of pixels (i.e. 0 or 1). As such, a pixel can only hold one bit of information. However, used as a group of NxM pixels, more information can be sent (i.e. characters, drawing, schematics, etc).

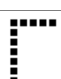
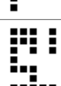
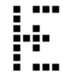
The authors have built a set of characters to facilitate the coding of the message. Each character is a small bitmap of 5x7. The patterns were carefully selected by a computer algorithm to ensure that each symbol is to be different from any other by a series of transformations such as : mirroring and rotation. The selection of 5x7 was done to optimize the spatial content of the message. Smaller characters would not have given a great deal of choices while larger would have taken too much place.

This set of characters is necessary to minimize possible sources of error while decoding the message. To illustrate the need for those criteria just look at the regular alphabet. Group of letters such as p-q, b-d and a-e-o, are too similar, could be confusion with each other in a noisy context. We want to avoid such possibilities.

Also, with enough bit difference between them it could be possible to read the whole message even with a lot of noise.

The alphabet can be compared to the ancient Egyptian hieroglyph system. Some characters represent a single idiom such as numbers or mathematical operators while others carried a more complex concept such as mass and length. Table I shows an example of the 1999 alphabet.

Table I. sample of the 1999 alphabet

symbol	meaning
	the number 1
	the number 5
	symbol "+"
	symbol "="

The alphabet is grouped into separate classes of symbols as listed in Table II.

Table II. sample of the 1999 alphabet

class	description
numbers	single numbers from 0 to 9
mathematics	operators, =, π, and some other concepts
units	units of measurement such as kg and meter.
chemistry	a short list of chemical element
physics	concepts of physics such as mass, energy, velocity, etc.
biology	some biology concepts
astronomy	symbols of planets
other	a series of miscellaneous symbols used throughout the message.

This coding scheme should allow the message to be read even if 10% of the bits transmitted are erroneous.

THE FORMAT

The reconstruction of an image from a bitstream is relatively simple. Even if the dimensions of such an image is not known a priori.

A Fourier analysis and a folding algorithm can be used to recreate the image providing that the image has some repetitive features.. For this purpose, we have encircled each page by a 1-pixel frame. The spectrum of the bitstream reveals a structure like a comb which is the signature of that frame.

TARGET SELECTION

To increase our chances of detection, we had to carefully choose the destinations. Such a task was quite difficult because we did not know much about the favourable conditions to the formation of Earth-like planets and of the apparition of life. Therefore, the target selection was an educated guest based on the following criteria :

- The targets must be visible for long periods from the Evpatoria Observatory ($\delta > 15$ degrees)
- They should be near the galactic plane where

the density of solar-like stars is maximum[7] (l < 90 degrees and |b| < 15 degrees). This is also supported by the META search if their candidates are genuine signals[8].

- Over long range (~ 1 kpc), scintillation should be minimized[9] (l ≥ 50 degrees).
- Stars listed in the SETI Institute's target catalogue that fulfil the previous requirements were selected
- Further selection bases on spectral type, duplicity, metalicity and age reduced even more the list.

THE 1999 MESSAGE

In 1999, we had just enough allocated time to transmit in the direction of four stars with three repetitions for each of them. In order to keep a descent signal to noise ratio with our transmission rate (i.e. 100 bit/s), target stars needed to be nearer than 100 light-years, even if our correspondent was listening to us with an antenna of one kilometre in diameter. From the list compiled by the SETI Institute, we picked up the stars, which can be observed easily from Ukraine. We focus our selection on stars near the galactic plane, simply because basic calculations show than the signal will reach an additional ten sun-like stars (plus many more cooler ones) beyond our primary targets. In fact, the signal may still be detected as far as 10,000 light-years by a 1-km antenna.

We also choose a region of the sky where the interstellar scintillation is minimal, between 60 and 90 degrees of the galactic centre. The final selection was made using spectral type, metallicity and age as criteria (Kevin Apps, University of Sussex, gave us a crucial help for this final step). We even managed to get a star in bonus, since our target star 16 Cygni A has a widely separated companion 16 Cygni B, which is know to possess an extrasolar planet.

Table III. list of target stars for the 1999 message

name	Spectral Type	Distance (lyr)
HD178428	G5V	68.3
HD186408	G2V	70.5
HD1900360	G6IV+	51.8
HD190040	G1V	57.6

The message is a set of 23 pages, each one of 127x127 pixels. The first page is shown in Figure I.

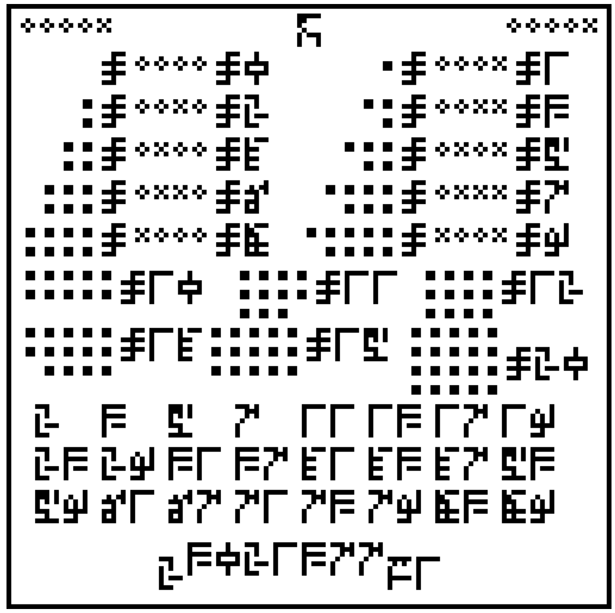


Figure 1. page 1 of the 1999 message.

As for the message content, the whole concept was resumed by Hans Freudenthal[10], who wrote in its book Lincos: “In the beginning, we shall communicate facts which may be supposed to be known to the receiver”. Subjects like Mathematics and basic Physics are very likely to be universal. It can be argued that an extra-terrestrial civilisation may not know Physics at all and their Mathematics might be quite different of our. However, a race able to received our message would have built a huge radiotelescope-like structure. It would probably have some kind of serious search for other intelligent civilisations. Therefore, it is quite difficult to imagine how this could be done without Mathematics and Physics.

So the message starts by teaching them how to count. Like on the Rosetta stone, three separate representations are used: groups of points, binary representation and our special symbols. The base 10 is used because it facilitates the writing and proof reading of the message. The lower part of the first page is a list of prime numbers. This short list ends with the largest prime found so far $2^{3,021,377}$-1. In the following pages, basic Mathematical operators are described, which will be used through out the rest of the message.

The last page of the Mathematical section describes basic geometry. A circle is used to introduce the notion of circumference and area, and the transcendent number π. Only the first 7 digits are written, followed by “...” (which has been introduced previously) and the last 15 digits. Those are the last of 51,539,600,000 digits found recently, and the sequence should be recognized as such. The Pythagoras theorem is also presented. It reinforces the notions of exponents and addition.

The next logical step is the introduction of physical concepts such as mass, length and time. It starts with a description of the hydrogen atom. Following that, the helium and the neutron are presented. A description of a sets of 12 atoms based on their number of protons and neutrons is next. This list includes the element #112; recently produced by a group of Russian scientists at the time of we wrote the message. The mass is defined using the ^{12}C atom and the Avogadro number. Follows the hydrogen spectrum from which the units of time and length are introduced At that point any physical definition can be derived from those basic notions (i.e. acceleration, temperature, pressure, etc)

Diagrams are used to describe these physical objects and it can be correctly argue than someone with a different culture may not understand them. The authors solve this problem by the use of fundamental ratios. For example, it is known that the proton is 1836 more massive then the electron and has an inverse charge. An extra-terrestrial scientist may not use the Bohr description of the hydrogen atom, but will certainly know the ratio of the mass between the proton and the electron.

In order to provide some information about us, a brief description of the Solar System, the Earth and the Moon is inserted. This is also an opportunity to reinforce the notions of time and length using the orbit of planets, if the receiver has access to this information from its own astronomical observations.

The message talks also about the humans populating the third planet from the star. A drawing of a man and a woman is shown along with a rule giving the height of a human. A description of our visual and auditive capacities is also given. Also, a schematics of the DNA and a cell is given. This kind of data could be very useful to introduce our type of life form.

The last part of the message presents a map of the Earth and some information about the signal itself. The authors give some information about cosmology and our evaluation of the age of the universe. This last step along with the largest prime, π and the element #112 shows that the human have enough resources at our disposition to go beyond survival and pursue scientific research simply for the knowledge.

In the last page, there ae some interesting questions the author would like to be answered by the receiving civilisation.

INTERNATIONAL REACTIONS

Protocols exist in the case of reception and it is not permitted to send an answer. However, there is no protocol preventing a deliberate sending of message.

Based on the article XI of the Outer Space Treaty, many tentatives to inform the following organisations have been made:

- Committee on the Peaceful Uses of Outer Space
- International Telecommunication Union
- Committee on Space Research of the International Council of Scientific Unions
- International Academy of Astronautics
- Commission 51 of the International Astronomical Union
- Commission J of the International Radio Science Union
- International Council for Science
- Inter-Union Commission on Frequency Allocation for Radio Astronomy and Space Science

No one reacted and every one let us transmit the message without any interference.

However, in Canada, a letter by the authors to the government has been leaked into the media which had produced the following reactions :

- "Canadian Defence Department Scientists On Alien Alert!" (National Post, February 2nd, 1999)
- "UFO chasers asked not to e-mail aliens" (CBC News, November 10th 2000)

THE 2003 MESSAGE

A second broadcast was performed in 2003. The message has been modified and include some changes. The format is no longer 23 pages but a single long page. During post-analysis of the 1999 message, it was found that vertical lines are more important for decoding than horizontal. This modification gave the authors the possibility to rearrange the whole text to be more space efficient.

The binary digits were kept as separators between sections. On the right side, the value decreases while it increases on the left. They count the number of lines. The could be used to know is part of the message is missing.

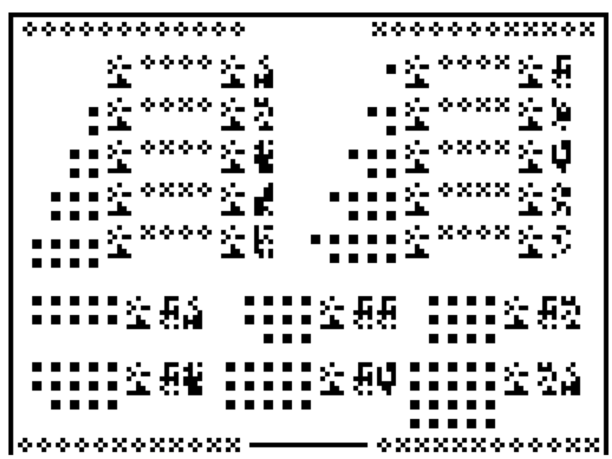
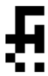
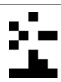


Figure 2. section 1 of the 2003 message.

Some items were dropped and some were added for clarity but basically it is the same content. Element 112 (ununbium) was replaced by the element 114 (ununquaternium).

The whole set of characters was rebuilt to be more resistant to noise. The 5x7 symbols was replaced by a 4x7 symbols for digits (i.e. 0 to 9) only. Since they occurred more often it was helpful to reduce there size. This also help separate the numbers from other characters.

Table IV. sample of the 2003 alphabet

symbol	meaning
	the number 1
	the number 5
	symbol "+"
	symbol "="

This time five new candidate stars were selected using the same kind of criteria as for the 1999 message. The message was repeated three time as well.

Table V. list of target stars for the 2003 message

name	Spectral Type	Distance (lyr)
Hip 26335 (Orion)	K7	37.1
Hip 45587 (55 Cnc)	G8V	40.9
Hip 4872 (Cassiopeia)	K5V	32.8
Hip 52721 (47 UMa)	G0V	45.9
Hip 7918 (Andromedae)	G2V	41.2

It is now known that some of the target stars have one or many planets. Like 55 Cnc which is likely to be a solar system with five planets.

CONCLUSION

Active SETI is quite new type of activity. Even is the probability of success is quite low, it raises serious ethical questions, which are not yet solved. But the broadcasting technology is well known and relatively accessible to any one with enough financial resource (as prove by recent commercial endeavours).

This work has been presented for the first time at the 1999 American Astronomical Society Meeting. Since then, the authors of the messages have participated to a few conferences and published a few papers. The whole project is done during our spare time. Since we do not have any funding, participation to conferences is quite difficult.

After writing and sending two messages, the next logical step is to try to understand a possible answer or even a completely different message.

Our current projects include the development of a cryptanalytic tool for SETI (i.e. the Young project, in honnour of Thomas Young) and trying to extend our own message. The authors start working on coding more abstract concepts such as equity, democracy and socialphysics but the work is still going on.

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