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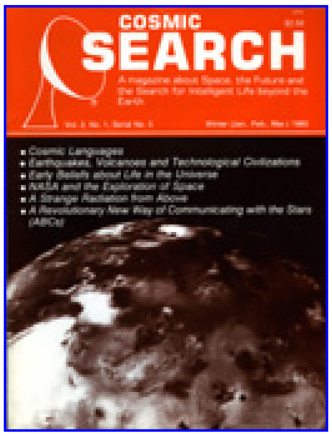

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Towards a Cosmic Language

By: Hans Freudenthal

Freudenthal

I have chosen the problem of designing a language for communication with rational beings who do not know any of the languages of our planet and to whom we cannot show things. We shall assume that they are akin to humanity in their mental facilities and development, though of course not necessarily with respect to their physical form.

This problem was the subject of an amusingly written but serious article published in 1896 by the brilliant mathematician and anthropologist Francis Galton. Today the technological possibilities for cosmic communication are much more favorable than in Galton's time. We now have electromagnetic waves on which we can send radio-signals into space. I do not know what distance they can cover at the time being. I am not an expert in communication engineering, and I am happy to leave such questions to more competent people. Nor can I say whether there are in fact rational beings somewhere in the universe who can receive and interpret our signals (though on this point my ignorance is not greater than anyone else's). However, I find it hard to believe that our earth is the only spot in the universe inhabited by rational beings, though I would be quick to admit that even if there are many mansions such as ours in our Father's house, our next neighbor could dwell thousands, even millions of light-years from here.

And then it might well be that this idea of a cosmic language is a belated inspiration. Perhaps news from remote worlds is incessantly crossing the universe on ether-waves, and the only thing we are expected to do is to listen. Perhaps they are travelling on wavelengths that cannot penetrate the curtain of our atmosphere, and in that case we will have to listen from an outpost in space, from an artificial satellite, and to build a station there so that we can listen to the network of cosmic communication. But these are fantasies for the physicist and the astronomer to toy with. Let us return to the proper subject of this article. I have made some effort to design a language for cosmic intercourse, which I call *Lincos* (an abbreviation of" Lingua Cosmica"). No doubt the reader will find I have achieved very little up to now. A volume of several hundred pages is necessary to expound a vocabulary of, say, two hundred words, excluding purely mathematical and logistic terms. And that is only the beginning. This vocabularly is tentative. It must be subjected to probing criticism, and analyzed for inconsistencies and needlessly clumsy constructions. Even aside from the technical difficulties we can hardly expect to be able to talk with other worlds in *Lincos* in the near future.

The sounds of Lincos are radio signals of different lengths and wavelengths. From these sounds words are built up. Only in a few cases have I prescribed how a word will be composed: for most of the words this is a rather unimportant question which may be left for future consideration. Instead of the *Lincos* words proper, which will consist of radio signals, I am using arbitrary code-words in my text. These code-words are written representations of the true *Lincos* words (as $ is for "dollar").

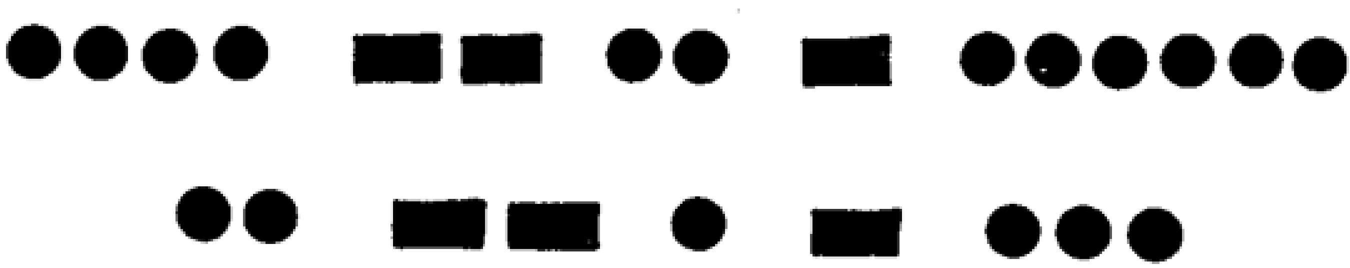
Out of these words sentences can be formed, which will be linked together in program texts. It is assumed that the listeners will recognize the stream of signals as a language and not as a celestial harmony. If they are at all like human beings, they will do with these messages the same thing we would do if we received them: they will try to decode them. They are not acquainted with the language, but in one respect their work will be easier than that of people who have to decipher a diplomatic or military code. Such codes are designed to resist all reasonable efforts at decoding and to be unreadable without the key, whereas in *Lincos* messages we shall do our best to make the text as clearly understandable as possible for the listener.

Designing a cosmic language has been made much easier by the work of the modern logisticians. The skeleton of the structure—the syntax—is ready. It is now the task of the workmen to pour the concrete and to lay the bricks—that is to say to create a vocabulary. In *Lincos* transmissions, pauses will be used as punctuation. The longer a pause the more emphatic it is as a punctuation mark. The listener will understand the principle without an explanation, if he understands anything at all. Pauses are self-explanatory.

First Words

But what shall we communicate? How can we start? With mathematics, of course. We cannot introduce things visually, hence our start cannot be concrete. And there is nothing as abstract as mathematics.

The first texts might be of this kind: four dots, a complex of signs we shall arbitrarily call POF, then two dots, another complex of signs we shall call RIK, then six dots. After this: 2 dots POF 1 dot RIK 3 dots.



The reader—and the receiver somewhere in the universe—are expected to understand that POF means "plus" and RIK means "equals". But that is a bit too hasty. The message could also be interpreted that POF means 'equals' and RIK means "subtracted from". Thus, 4 equals 2 subtracted from 6.

Obviously, then, this was a false start. Designing a language means crossing a field with a great many snares, and I am sure I have fallen in quite a few of them. Let us start more cautiously, with sentences that contain no more than one doubtful word, for example 4 dots RIK 4 dots,

and so on. With the meaning of RIK as 'equals' made clear, we can send sentences of the first type without danger. In the same way we can introduce words expressing the other fundamental operations of arithmetic, and terms denoting 'greater than' and 'less than'. We shall simply send numerical formulas in which these words appear. Excluding the infinite number of numerals 1, 2, 3 ... denoted by one, two, three, or more dots, we then have at our disposal a vocabulary of seven words. These are plus, minus, multiplied by, divided by, equals, less than, and greater than.

Dot-numerals are, of course, too clumsy in the long run. In due time we shall send a list telling the receiver how to transcribe numbers in a more compact way. We shall naturally not use decimal notation, but binary, for there is no reason to suppose that rational beings of other worlds all have ten fingers and ten toes. But for the convenience of the terrestrial reader I shall here stick to decimal notation.

The next step is to introduce variables. We shall send a sequence of equations like 3+7=7+3, 3+11=11+3, 3+1=1+3, 3+8=8+3, and finally 3+A=A+3, from which the listener must conclude that the unknown complex A must designate a variable. Gradually such formulas with "letters" will be made more and more complicated.

Then the first logical symbol can be introduced. We shall transmit pairs of algebraic formulas, each pair such that the second element always follows from the first, and between them a word that should be interpreted as 'implies'. From the context the receiver will be able to conclude that the word does have meaning. In the same way words meaning "and" and "or" can be introduced.

Zero, negative numbers, and fractions will then be established in contexts which recall those of secondary-school algebra. The next step is that of decimal (or rather binary) fractions. Common fractions are converted into the binary system. And with the introduction of repeating fractions it will be possible to familiarize the listener with the one term that is the key to all mathematics: the term "and so on", which will become one of the most frequent *Lincos* terms. Then words are introduced meaning "integer" and 'fraction', and a word meaning "is" as used in the statement "3 is an integer".

Time Concepts

The second chapter of *Lincos* bears the heading "time". A message is sent consisting of an as-yet-unknown word, say DUR, a rather long dash, the word meaning "equals", another unknown word, say SEC, and finally a numeral equalling the actual duration of the dash measured in seconds.

The message, then, would mean that the duration of the dash equals so and so many seconds. This message will then be repeated with another length of dash (and consequently with another numeral following it).

If this is done a number of times the listener will notice that the number in the message is always proportional to the length of the dash, and he will conclude that the unknown word DUR means duration and that SEC designates our conventional time unit.

"It is easier to forget something you don't want to forget than to forget something you do want to forget."

In the same way we can also introduce "wave length" and "frequency". Similarly the ideas "before" and "after" can be demonstrated by means of a pair of dashes on different wave lengths and a text that states: dash on wave length x before (or after) dash on wave length y. Then a clock can be installed on a fixed wave length, ticking in the background through the whole program, with directions added how to "read" the clock. From then on if we wish to mention a past or future event, we shall be able to quote it by its date. Mentioning events will be illustrated by many examples: a certain event is produced (for instance a complicated sequence of signals), and afterwards it is stated that "between moment 1 and 2 such and such happened", with "such and such" replaced by a replica of the event that had happened. In this way the receiver will learn that the *Lincos* word used means "happen".

More Advanced Concepts

The third chapter of *Lincos* deals with human behavior, the most substantial and the most difficult chapter up to now. Of course, we cannot tell the receiver anything about humans in abstract terms. In the same way we demonstrated numerals by sequences of dots and durations by dashes, we will now stage human behaviour in a sort of radio-play. The actors will have arbitrary names, say Ha, Hi, Ho and so on. Of course these actors must display some sort of activity, and as no words are available to indicate space or movement, the only activity we can have them perform is that of speaking. Speaking, that is to say communicating; it does not matter for the moment what physical methods of communicating are used on earth. But besides actors and an activity we need a third feature, some means to distinguish between good and bad actions, for it is impossible to stage good actions only. So we shall put two words, "right" and "wrong", in the actors' mouths as signs of approval or disapproval.

Finally, we must decide what subject we want the actors to talk about. Of course, it will be mathematics, for mathematics has been previously outlined in detail, and there is no other subject available. The conversation will consist of questions and answers in classroom style.

The first conversation might run like this:

> Ha says to Hi: "?X (X=2+2)"
> Hi says to Ha: "4"

Ha says to Hi: "Right"

A good many similar conversations will be transmitted. The sequences of alternating questions and answers will evoke an impression of conversations, and the listener will guess what "says to" means and that Ha, Hi, Ho ... are names of beings who can converse. Since correct answers are followed by "right" and poor answers by "wrong", the receiver will guess what these words mean.

For our conversations we can dispense with a vocabulary of interrogatives, since each question can be formulated as a problem of finding an unknown. Thus, "who said to Ha:

2+2=4?" can be verbalized:
"?X (X said to Ha 2+2=4)"

Or "what did Ha say to Hi?" would run:

"?X (Ha said to Hi X)"

And finally "Did Ha say to Hi: 2+2=4?" can be expressed:

"?X [X=truth value (Ha said to Hi 2+2=4)]"

Now we can proceed to stage a few other actions which are actually elaborations of the act of speaking, most of them speaking with oneself. A series of dots is broadcast, and at the same time Ha counting them, that is to say pronouncing numerals. Afterwards Hi states, "Ha has counted". Or we hear Ha making a calculation, and then Hi says, "Ha has computed". He tries to find something (say the first prime number beyond a certain bound, by calculating, or a person who said something, by repeating the question "did you say that"), and afterwards Hi states that "Ha has searched for (and found)". "Proving", "describing", "modifying", "adding", "dropping" can be demonstrated by the same method.

"Knowing" is a much more difficult term. Conversations are started in which Ha asks Hi how much 2+2 is; Hi answers "4", and subsequently Ha states that Hi "knows". This, however, is not sufficient. Less direct methods can better demonstrate what "knowing" means. For instance, Ha asks Hi how much 2+2 is, and Hi answers "4". Ha then says, "Hi knows what I have asked".

The next word is "perceiving". It appears that Hi has knowledge of a certain event although nobody has told him about it; Hi knew it as soon as it happened. Hence Ha states, "Hi perceived it". This word requires a broad context. The words understanding" and "slip of the tongue" are easier. They can be illustrated by simple examples.

A very important and rather easy word is "nearly". Approximate solutions of algebraic equations, approximate imitations of noises, and so on may serve to put this word into a context.

A rather simple word is "age" (of a person). Ha states that Hi was not able to perceive a certain event, because it happened too long ago, and from this Ho concludes that Hi's age is less than a certain number of seconds. The beginning and the end of a human "existence" are defined as the limits within which that individual can have observed something—a provisional definition that is sufficient for the moment. A chart of individual development can be added: at what age a human can speak, count, calculate, solve quadratic equations, and so on.

Then a new actor Ba enters. Ba can observe events and produce unintelligible sounds, but cannot speak, count, calculate, and the like. It will then be stated that Ha, Hi, and Ho belong to the class "human", whereas Ba is a member of the class "animal"—a class which will not be subdivided for the time being. A short statistical survey of living mankind according to age classes can be added at this point.

Now we can turn to a category of words like "wishing", "permitting", "being obliged", "being allowed", "forbidding", "it is decent", "it is polite". A person who is addressed refuses to answer: "I don't want to... " Persons announce that they, or other persons, will do something, with the formula "I want to ... " Two persons "promise" to each other that they will do something, and a third person states that consequently they are "obliged" to do it. A liar is "called upon" to speak the truth. One is "allowed" to say "I want you to do this", but it is more "polite" to say, "May I ask you to do this?"

This conflict between necessity, duty, will, power and possibility reaches its climax at the end of this chapter on human behaviour, when games are organized among the actors. Such games will end with the "victory" of one of the partners and the "payment" of a forfeit by the other. Ha and Hi play a very simple arithmetical game: by turns they choose a number between one and ten. All the numbers are added together. The person who passes the hundred mark wins the game. Or Ha and Hi gamble, playing something like "matching pennies": simultaneously and independently of one another they say either "one" or "two". If they have chosen the same number, Ha wins, if the numbers are different, Hi wins. And finally there are games for three persons: two of them can combine against the third, who will try to break the alliance by offering advantages to one of the allies.

Although the subject matter of the conversations is still dominated by mathematics, and behavior is primarily rational, we can already account for the emotional background ofthat behavior. The rather sophisticated character of the talks now possible might be illustrated by an example that in common language would run as follows. Ha makes a statement to Hi. Then he perceives that Ho might have heard what has been said. Ha asks Ho whether he has heard, and Ho confirms that he has. Ha asks Ho if he will be so good as not to remember it. Ho answers: "I will try to forget, but I don't know whether I can, for there are many things which are immediately forgotten, but there are also things which are remembered all one's life. It is easier to forget something you don't want to forget than to forget something you do want to forget."

Concepts of Space, Distance, and Motion

The fourth chapter of *Lincos* deals with mechanics, but human behavior still plays a part in it, though on another level. Human beings, as introduced in the third chapter, had one dimension only: time. There was no space in which they could move; no mention was made of their bodies. The actors who spoke, who expressed and imposed their wills, and played and fought together, were nothing but vague shadows.

The first new concept in this chapter is that of "difference in location". Ha and Hi perceive the same event at different times, hence are in different places. Distance is defined: the distance between Ha and Hi is proportional to the delay a message from Ha to Hi undergoes. Space is then defined as that which embraces all places and within which distances are given. After this experimental introduction space and distance can be defined in a strictly mathematical sense, with the aid of analytic geometry. By means of it spatial figures can be described in formulas. Of course the receiver does not yet know our unit of length. The only absolute measures we can indicate at this point are the average length and volume of adult people, and no more than rough estimations of our unit of length can be derived from such data.

"Motion" is introduced by telling about humans and animals who change place, then soon afterward redefined with mathematical precision. Humans and animals can move by their own will, things cannot. Humans and animals can move things with them and away from them; they can carry and throw things. As an amusing interlude three persons play ball.

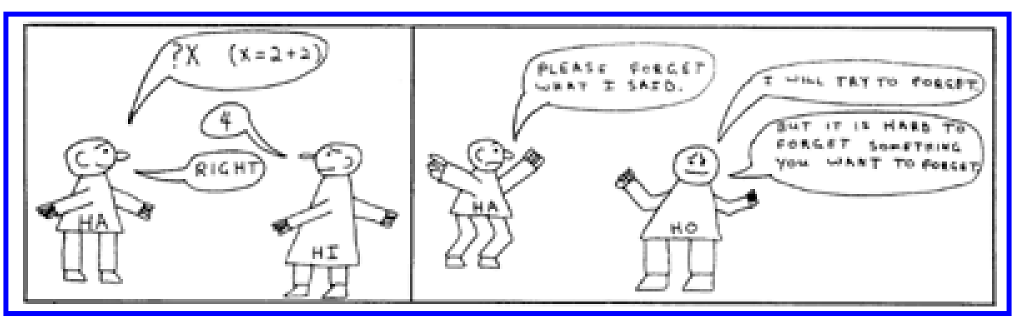
A special kind of motion is that of waves and oscillations. There are oscillations which propagate with a huge velocity, called light (or radio). The speed of light can now be indicated, and the receiver who more or less knows our time-unit can now translate our unit of length into his by comparing our data on light with those of his own experience. After this we can communicate a formula comprising the wave lengths emitted by the hydrogen atom. This formula contains the so-called Rydberg constant, from which our unit of length can be derived with much greater precision.

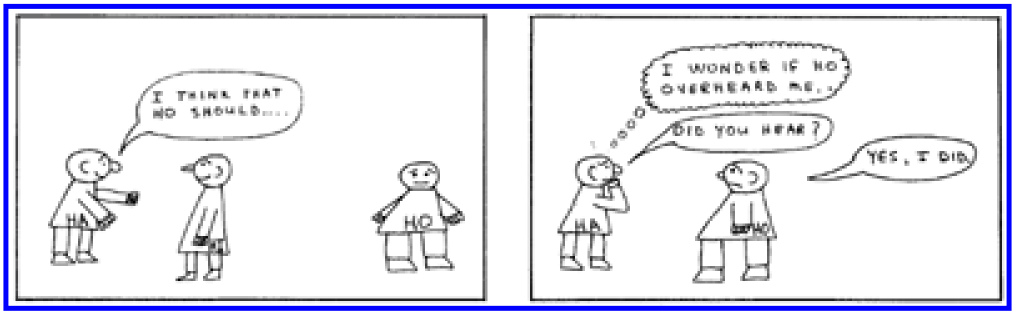
The next notion is that of "mass". An actor states that of two things one is more difficult to carry than the other. They have the same volume, so the difference is due to another factor, mass. Then a collision is reported and explained by the classical laws of elastic collision. From this the receiver can conclude what we mean by mass, though our unit of mass is still unknown. We can then describe phenomena of "gravitation" and state Newton's law. By comparing it with the law of his own Newton, he will be able to calculate our unit of mass. These are fundamental notions of mechanics.

We have also reported that humans, animals, and things have a characteristic that may be called a body, which can change in the course of time. The average mass of human bodies can be indicated. Then we can describe where and how human bodies come into existence.

Afterwards reference can be made to bodies with masses so large that they must be celestial bodies: the sun, the planets, and the nearest fixed stars. The masses, orbits, velocities, and so forth of the planets in our solar system will be quoted, and then one of those bodies can be specified as the residence of mankind. If we then proceed to draw a map of our part of the universe, the receiver beyond our solar system will be able to seek out the spot where mankind dwells.

This fourth chapter is concluded with an exposition of relatively — an indispensable theme, for without it there would be serious inconsistencies in our broadcasts. The subsequent chapters are planned to deal with matter, geography, anatomy and physiology, and, for a second time, human behaviour. These chapters still have to be worked out. Meanwhile the four themes sketched here are described in detail in the first *Lincos* volume.





This article is adapted from an article of the same name published in the summer 1958 issue of "Delta — A Review of Arts, Life and Thought in the Netherlands." It describes and introduces Prof. Freudenthal's famous book" *Lincos* — Design of a Language for Cosmic Intercourse" (North-Holland Publishing Co., Amsterdam, 1960).

It should be noted that the author's primary intention was not to develop a language, but to give an example of how the science of logistics can be applied to solve interesting and significant problems. Nevertheless the language has become widely known as an "existence proof" that ways could be found to converse with other civilizations. Further details of the logistics background of *Lingua Cosmica* may be found in the book or the original "Delta" paper.


Freudenthal

Hans Freudenthal was born in Luckenwalde Germany in 1905. He studied mathematics at Berlin and Paris Universities, and was on the faculty of Amsterdam University from 1930 to 1946. He served as professor of mathematics at Utrecht University, Netherlands from 1946 to 1976, with visiting professorships at the University of California in Berkeley, Yale University, and Pennsylvania State University. From 1964 to 1965 he was Rector of Utrecht University. He has received honorary doctorates from Humboldt, Erlangen, Brussels, York and Amsterdam Universities.

His research has been in the fields of topology, linear analysis, probability, geometry, Lie groups, logic, the history and philosophy of mathematics and mathematical education. He has written several hundred papers and several books in the field of mathematics. He is still associated with Utrecht University and since 1970 his primary work has been the development of mathematical education programs.

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Designed by Jerry Ehman.
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