Book Review

Lincos, Design of a Language for Cosmic Intercourse, Part I: Hans Freudenthal; 224 pages; $6.25; North-Holland Publishing Company, 1960. Reviewed by Joseph Blum. (Unclassified)

The exploration of outer space has begun and it is expected that serious scholars will begin to consider various problems associated with cosmic communications. In this book the author sets for himself the task of designing a language for cosmic communication. Professor Freudenthal, a professor of mathematics at the Univêrsity of Utrecht (and recently a visiting professor at Yale), brings to this task the capabilities of the mathematician, teacher and linguist. The language developed by Freudenthal is called Lincos (his acronym for "lingua cosmica").

Considering the difficulties in the way of establishing physical communication with our nearest cosmic neighbors, we must agree that such communication is remote from now. However, if such communication is ever to become a reality we must begin to solve some of the problems that the author recognizes and attacks. The author is primarily concerned with the development of formal language for the purpose of communication. As a first goal he chooses "to design a language that can be understood by a person not . . . acquainted with any of our natural languages or even their syntactic structures." How well the author has succeeded is subject to debate. There are no means available to objectively evaluate the language under the stated terms of reference. In fact, the terms of reference are not well defined. The author assumes "that the person who is to receive my messages is human or at least humanlike as to his mental state or experiences . . . Yet I shall not suppose that the receivers of my messages must be humans or humanlike in the sense of anatomy or physiology."

What makes the problem even more intriguing is that Lincos must be taught to the receiver under challenging circumstances, i.e., with no previously established means of communication and with messages sent in only one direction—from teacher to student. Under these constraints, the first few lessons in Lincos are crucial, for if they are not understood everything which follows will be incomprehensible. To meet this difficulty, the author proposes to begin by communicating facts which can most assuredly be supposed to be known to the receiver and by using the simplest and most reliable didactic principles. Mathematics is selected as the subject with which to begin the teaching program for it "may be supposed to be universally known to humanlike intelligent beings."

The definite program to be broadcast will consist of a large number of pieces called program texts. The material presented in the book is considered to be an abstract from the definite program. The program texts have been collected in paragraphs and chapters. The chapter titles are I Mathematics, II Time, III Behaviour, IV Space, Motion, Mass. Further chapters on "Matter", "Earth", "Life" and "Behaviour" are planned by the author in a second volume on Lincos.

There are two versions of Lincos—(1) spoken Lincos, which is broadcast and in which the information is quantized into phonemes and (2) written Lincos, a conveniently coded form suitable for printed exposition such as the author's book. Lincos notation borrows heavily from mathematics and the Lincos words are abbreviations or contractions from the Latin equivalents. Thus the Lincos word *Num* means "natural number" (from the Latin *numerus*). Punctuation is the principal means of showing Lincos syntactic structure. The Russell-Whitehead system of dots is adapted for use as containment symbols although the conventional usage of parentheses might have been a better choice for the readability of Lincos.

Chapter I sets out first to introduce the natural numbers, the order relations and the operations of addition and subtraction. The abstract from the factual program is as follows (# used for "begin" and "end" marks):

1. # · · · · · > · · · # etc
2. # · · · <· · · · · # etc
3. # · · · · = · · · · # etc
4. # · · · · + · · = · · · · · · # etc
5. # · · · · · · · − · · = · · · · # etc

In this text the Lincos phoneme corresponding to the round dot is a short radio-signal (a peep). A Lincos word consisting of n successive phonemes of this kind both means and shows the natural number n. In the next lesson these numbers are superseded by numbers in binary notation. The program text begins with

· = 1
· · = 10
· · · = 11
· · · · = 100
· · · · · = 101 #
etc.

From this point on all numbers are represented in binary notation. The author proceeds to introduce the concept of a variable and to

develop the concepts of the logical connectives. The fundamental facts for the number systems are presented—first for the integers, then for the rational numbers, the real numbers and finally the complex numbers. By the end of the chapter there is enough apparatus to deal with the formal definition of group and field using the familiar axioms of modern algebra. The chapter terminates with a presentation of the basic facts of the propositional calculus. The Lincos vocabulary at this point includes such words as "true", "false", "proposition", "question", and "truth-value". It is highly plausible that the Lincos language of Chapter I could be learned by a human-like person acquainted with our kind of mathematics.

Chapter II is designed to teach all the basic temporal concepts and relations. As in mathematics, the start is made with the use of ideophonetic signs. Time signals of various duration and wavelength are shown together with numbers and symbols. In this way the unit of time is introduced. Duration, frequency and the number of oscillations are introduced. Words are introduced meaning "begin", "end", "before", "after", "precedes", etc. Finally a time-clock is installed to serve as a frame of reference for all further communications about events. The linguistic devices which are used to name and describe events can be expected to be harder for the cosmic pupil to penetrate. Perhaps the author expects the subsequent program texts in later chapters to provide help in exposing the semantics of this area of Lincos.

Chapter III, on human behaviour is the longest, most difficult and most interesting chapter in the book. To cope with this complex topic, Lincos must be augmented with the essential elements of vocabulary and grammar which are common to most natural languages. Behaviour is displayed by presenting short one-act plays. The first of these are very simple and consist of dialogues. The author begins by showing good and bad behaviour and introducing words which mean "good" and "bad". At the outset these words simply indicate approval or disapproval. As an example of the technique, consider the following texts presented in a free English translation of Lincos:

A speaks B : ?x (2x = 5)
B speaks A : 5/2
A speaks B : good
. . . . .
A speaks B : ?x (4x = 10)
B speaks A : 10/4
A speaks B : bad
B speaks A : 1/2
A speaks B : bad

B speaks A : 5/2
A speaks B : good
. . . . .
A speaks B : ?x ($x^2 = 25$)
B speaks A : $5 \times 5 = 25$
A speaks B : bad
B speaks A : $(5 \times 5 = 25)$ is true
A speaks B : true but bad; not $(x^2 = 25 \rightarrow x = 5)$
B speaks A : 5 or -5
A speaks B : good

Another clue which helps to distinguish "good" from "bad" is contained in the text:

A speaks B : ?x ($4x = 10$)
C speaks A : 5/2
A speaks C : bad
B speaks A : 5/2
A speaks B : good
. . . . .

From these very modest beginnings the author rapidly develops enough language to display rather complicated behaviour. Here are some examples:

1. An individual recites a short history of Fermat's theorem on the existence of solutions to the equation $a^n + b^n = c^n$.

2. An actor agrees to give information about a certain event on condition that the other will keep the information secret. When asked about this event, the other refuses to give the information because he has promised secrecy.

3. A bet is made on solving a cubic equation. The winner refuses to tell the general method of solution. The loser refuses to pay. An arbiter is called in. The winner then tells his method and the loser pays up.

There is little doubt that the lessons contained in Chapter III constitute, for the learner, the major hurdle in mastering the Lincos language. With the support of some generous foundation, experimentation with people might develop enough evidence to determine the plausibility of success. Quite apart from settling this question, such research might yield results which could be applied to the learning of foreign languages and to the design of more powerful problem-oriented programming languages.

In Chapter IV the author introduces the basic physical concepts such as length, mass, velocity, acceleration, density, etc. Mechanical

concepts are introduced by acts of behaviour and later embedded into a mathematical system. The physicists will be interested in the author's discussion of the various ways to introduce the concept of length. He decides to do this indirectly by indicating the numerical value for the velocity of light. This information together with the knowledge of the time unit then makes it possible for the receiver to deduce the unit of length. The author furnishes opportunities to confirm correct conjectures by supplying physical and astronomical data such as Rydberg's constant for hydrogen, the universal gravitation constant, the mass of the hydrogen atom, distances between astronomical bodies, etc. The texts discuss such things as elastic collision of bodies, the law of universal gravitation and the solar system. The chapter concludes with a brief discussion of relativistic mechanics and a derivation of the well-known mass increase formula.

To assist the reader, the author has provided a summary of the program texts and a register of the symbols and vocabulary of Lincos. The printing of the text maintains the high quality and standards which have been exhibited in the publisher's series entitled Studies in Logic and the Foundations of Mathematics. The reviewer warmly recommends this book to all who enjoy a delicious potpourri of mathematics, logic and linguistics.

——J. B.