Key To The Extraterrestrial Messages

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Dr. Campagne presented a series of 29 messages from outer space in "Extraterrestrial Intelligence," NSA Technical Journal, Vol. XI, No. 2, pp. 101 ff. and in the Special Mathematics and Engineering Issue of the Journal, pp. 117 ff. The following article develops a key to those messages. Paragraph numbers parallel the serial numbers of the messages reprinted in the appendix below. This includes two new series--30 and 31—not included in the previous article.

At every step in the solution we make a guess at the meaning. Evidence will quickly accumulate to verify or refute this guess. The possibility of ambiguity of two consistent solutions is very remote. Only in the last steps, where verification is thin, could this happen.

1. There are 21 symbols, in the order given by this message.
2. B is equivalent to AA, C to AAA, etc. That is, A = 1; B = 2; C = 3; D = 4; E = 5; F = 6; G = 7.
3. The symbol L means the two things that follow are the same.
4. Each statement has 5 symbols, and begins with L. The 4 symbols after L must be considered as two things. Each statement has a K as the third letter, which must be the start of the second thing. Is B = KAA; C = KBA; C = KAB; D = KCA? If KBA means B + A, it fits.
5. These verify our conclusions on 4. The first means 6 = 1 + (2 + 3); the last means 1 + (1 + 1) = (1 + 2) + 3.
6. Each has five symbols as in 4. They mean 1 = M21; 2 = M31; 1 = M32. Obviously MXY means x - y.
7. These translate N = I = 1; N = 2 = 2; N = 3 = 3. N stands for zero, 0.
8. These translate 1 = O11; 0 = O11; 2 = O12; 2 = O12; 0 = O20; 4 = O22, etc. OXY means the product X × Y.
9. These verify the conclusions of 8. The first says that 6 = 1 × 2 × 3, the last 4 × (5 × 6) = (4 × 5) × 6.

Note: So far we have seen two kinds of symbols: digits A through G and N, and operators L, K, M, and O. The two digits following the operator are the operands.

10. Translates into 4 = R22; 2 = R21; 1 = R20; 3 = R31; 1 = R30. RXY must mean X', exponentiation. R is another binary operator.
11. Translates into $2^4 \cdot 4 + 4; 2^4 = 1 + 7; 2^3 = 2 \times 4; 2^4 = 4$, verifying our previous conclusions.

12. Translates into $3^4 = 4 + 5; 3^3 = 3 \times 3$. Further verification.

Note: In our culture we use parentheses to group closely associated terms, and as a first step it helps, even though it is not necessary, to put in parentheses. To do so unambiguously, start at the right and read left to the first operator symbol; put parentheses about the operator and the two quantities to its right. Repeat until no pair of parentheses contains more than an operator and two quantities.

13. Translates into $J = 2^3; J = 1 + 7; J + 1 = 3 \times 3; J + 1 = 3^3$, therefore $J = 8$.

14. We can only introduce parentheses by assuming $P$ is an operator, so we get $2 \cdot P84; 4 \cdot P82; 1 \cdot P33; 3 \cdot P62$. Thus $P 	imes Y = X : Y$, division.

15. Assume $U$ is an operator, getting $U12; U23; U34; U58; U68; U78; U2^3 = 89$. The smaller is first in each case; so perhaps $UXY$ means $X$ precedes $Y$ or $X < Y$.

16. The new character $Q$ must be an operator. Transcribed it gives $Q: O = 1; Q: 1 = 1 + 1; Q: O = 1 \times 1; Q: 2^2 = 2; Q: 2 \times 2; Q: H(1 = 1) (1 = 2); Q[Q: 3 = 3]; Q: 8 < 7$.

Clearly $Q$ means the following statement is false.” Then the next to the last is read “it is false that $3 \neq 3$.” $Q1$ will be translated $\neq$. The second new symbol is not clear, except that it is an operator whose operands are statements, not quantities, a Boolean operator.

Note: $Q$ is an operator with only one operand, unary.

17. Putting in parentheses shows that $S$ is also a unary operator operating on statements. Transcribed they are: $S: 1 \cdot 1; S: 1 \cdot 2; S: 2 \cdot 1 \cdot 1; S: 1 \cdot 1 \times 1; S: 0 = 1 \cdot 1; S: H(6 \cdot 1 \times 6) (1 \cdot 6 \cdot 6); S: H(1 \cdot 1) (2 \cdot 2)$. It is apparent that $S$ means the following statement is true” or “it is asserted that.” The next to the last message shows that $UXY$ means “$X$ implies $Y$” or “$X$ is a consequence of $Y$” or maybe “$X$ is logically equivalent to $Y$.”

18. Our rule for parentheses breaks down unless $T$ is a different kind of symbol. The first message shows that $T$ may be a unary operator on quantities, so that $AT$ or $TA$ is a quantity. The third message shows that it must be the first, since $T$ is last. Putting in parentheses this way gives $1T = 1; 2T = 1T + 1; 3T = 2T + 3T; 6T = 3T \times 2T; 7T = 7; 10T = 80$. $T$ must be an ending. On one digit it makes no difference. It combines the two digits 10 to make 8. Octal arithmetic?

19. Transcribes to $123T = 1 \times 8^2 + (2 \times 8^1 + 3); 321T = 3 \times 8^2 + (2 \times 8^1 + 1 \times 8^0); 4567T = (4 \times 8^2 + 5 \times 8^1) + (6 \times 8^1 + 7 \times 8^0)$.

Clearly $T$ indicates that “the preceding digits form an octal number.” Possibly it is an octal point; if so, digits may occur after it.
Note: Because of the way grouping is implied, it is sufficient to have a marker at the end of a number in order to clearly isolate it as a single entity.

20. In trying to put on parentheses it appears that V is also an ending. But this one combines with both quantities (that is, digits) and operator. Transcribing by treating V and the preceding symbol as a single unit for the time being, we get:

8 1 + AV implies 7 = AV.
I will use · for · hereafter. Remember that we are not sure of the sense of this sign. 11 · 311 = · 2 = AV (I have omitted the T. Remember that 11T is nine);
3 AV = · 11 = AV;
5 AV · 6 · 11 AV.

In the next message if we combine the O and V into one symbol the message does not parse. Try GOV as one symbol, getting
3 1 + GOV · · 2 = GOV;
6 2 × SOV · · 3 = SOV;
3 DOV · · 11 = DOV;
It is true that AV + PV = PV + AV;
It is a tautology that AV × PV = PV × AV;
It is an identity that AV + (PV + TV) = (AV + PV) + TV;
It is asserted that AV × (PV × TV) = (AV × PV) + TV;
AV × BV · · AV × BV × BV × AV;
AV × BV · · AV × BV = BV × BV.

The meaning of V must be that “the preceding letters as a group have an abstract meaning, or are a variable.” V is a little like a word spacer.

Note: Putting in parentheses is now complicated by another rule. Each T or V should be packaged with preceding symbols, just how many depending on the parsing of the message. Those preceding T will all be digits. Those preceding V can be expected to reoccur as a group.

21. Putting parentheses in these messages is difficult until we notice that UV appears in each. They then transcribe into:

0 2 + [(DDD)2 = DDDD × 3] = · UV[1 = DDDD]
[2 + DDDD];
UV[1 · DV] [0 · 1 = DV] · [1 = (DV)];
UV[1 · BV] [0 · BV] · 0 = BV − BV;
It is true that UVAV = BV [AV × BV];
It is true that UVAV < BV [BV < AV].

In order to complete the parsing we had to assume that UV was a binary operator, and in every case the operands are statements. It is clear from the algebra that UV means “or.” The last message shows that 1 means < , rather than < as I had it.
22. We notice that TV is used in every message, and parallels the usage of UV. Assuming TV is a binary Boolean operator, the messages parse.

\[
\begin{align*}
\text{It is false that } TV & \{AV \leq BV \} \{BV \leq AV\}; \\
\text{It is false that } TV & \{AV = BV \} \{AV \neq BV\}; \\
TV & \{\overline{AV} = 4\} \{0 \leq AV\} = AV = 2; \\
AV & > BV = \{BV \leq AV\} \{BV = AV\}; \\
\text{It is true that not } TV & GY IV = \{GY = IV\}; \\
\text{It is true that } GV & HZ = \{TV = GY IV\}; \\
\text{AV or } (BV & or CV) = (AV or BV) or CV; \\
TV & \{TV [TV [BV CV]] = TV [TV AV BV CV]\}; \\
TV & \{AV [BV or CV] = TV [AV BV] or TV [AV CV]\}; \\
AV or TV & \{BV CV\} = TV [AV or BV] [AV or CV]. \\
\end{align*}
\]

It is apparent that TV means "and." Notice that L is used here to mean "logically equivalent to." although I have written "= ."

Note: U is used here for <, not ≤ .

Either there is a mistake, or the usage varies.

23. The parsing falters until we realize that JNV occurs in each message, and is probably a word. BAV and CAV also occur in each message. They transcribe into:

\[
\begin{align*}
JNV & \{BAV or CAV\} BAV; \\
JNV & BAV \{BAV and CAV\}; \\
JNV & \{BAV or CAV\} \{BAV and CAV\}; \\
JNV & BAV CAV =, BAV = (BAV or CAV); \\
JNV & BAV CAV =, CAV = (BAV and CAV). \\
\end{align*}
\]

The last two conclusions look like set theory statements. JNV parses like a binary operator. JNV XY could mean "X contains Y" in the set theory sense. Then if UV is "or" in the set theory sense, the union, and TV is "and" in the set theory sense, the intersection, the statements above can be rewritten:

\[
\begin{align*}
BAV \cup CAV & \supseteq BAV \\
BAV & \supseteq BAV \cap CAV \\
BAV \cup CAV & \supseteq BAV \cap CAV \\
BAV & \supseteq CAV =, BAV = (BAV \cup CAV) \\
BAV & \supseteq CAV =, CAV = (BAV \cap CAV). \\
\end{align*}
\]

24. NKV looks like a binary operator of which at least the first operand is a quantity. JAV is uniformly the second operand. From 23 above we are alert to set theory statements. Could it be that NKV says something is a member of some set? Try it. They become

\[
\begin{align*}
1 & JAV; 2 & JAV; 3 & JAV; 4 & JAV; 5 & JAV; 6 & JAV; 7 & JAV; 11 & JAV; \\
12 & JAV; AV & JAV =, AV + 1 & JAV. \\
\end{align*}
\]

JAV is the set of positive integers! It fits!
25. These parse into:
(I and 2) JAV;
(1 and 2) and 3) JAV;
(14 and 17) JAV;
(177 and 100) and 101) JAV;
(AV ⊔ NMV) and (BV ⊔ NMV) = (AV and BV) ⊔ NMV;
0JAV;
8cJAV; 8dJAV; 8eJAV; 8fJAV; \ldots;
B\text{V}JAV = 8\text{v}JAV;
(BV and CV)JAV = (BV \lor CV)JAV;
(BV and CV)JAV = (BV \times CV)JAV;
(BV and CV)JAV = (BV \lor CV)JAV;
1/2JAV; 1 - 2JAV; 0 - 3JAV; 7/6JAV.

This verifies beyond doubt the guess of 24.

26. There is a new word, JOV. The messages read JAV\text{eJOV}:
0 1Jov; 0 - BV\text{eJOV} = - BV\text{eJOV};
1/2Jov; AV and BV\text{eJOV} = - AV - BV\text{eJOV};
(AV and BV in JOV) and 0 \neq BV = - AV \lor BV in JOV;
1 : 0 in JAV; 1 : 0 not in JOV;
It is true that (AV \land BV) \times (CV \lor DV) = (AV \times CV) \lor (BV \times DV);
It is true that AV \times DV < BV \times CV = - AV \lor BV < CV ;
DV, BV \times DV \neq 0;
AV\text{eJAV} - 0 \lor < AV.

JOV is seen to be the field generated by JAV, in other words, the set of rational numbers. The next to the last message has a garble, an extraneous A.

27. This transcribes to:
(AV \lor - BV) and (BV \lor AV) = - HV.AV.BV.
Clearly HV means "logically equivalent," or "\ldots .
(AV \lor - BV) = - (AV = - BV) and (BV = - AV)
(AV \lor - BV) = - (AV = BV) and (BV = - AV).

28. These transcribe to
\overline{GV} = 3 \Rightarrow GV not in JOV;
\overline{GV} = 2 \Rightarrow GV not in JOV;
\overline{GV} = 5 \Rightarrow GV not in JOV;
GV = 5 \Rightarrow GV in JEV;
JOV is in JEV;
JAV is in JEV;
GV = 0 - 1 \Rightarrow GV not in JEV.

We have a new set, containing the rationals, and at least one irrational, but not the imaginary \sqrt{-1}. JEV is probably the real numbers.
29. These transcribe to

- \(2^n \) in JBV; \(1 - 3^n \) in JBV;
- \(4^n \) in JBV; \(1 - NV^n \) in JBV;

\( NV \) JBV \( \rightarrow \) 1 [assuming \( NV \) is one word. Another possible parsing is \( LV(JBV, 1) = 0 \)]

- \(1/1\) in JCV; \(1/2\) in JCV; \(1/3\) in JCV; \(1/NV\) in JCV; \( NV \) JCV \( \rightarrow \) 0. But the two examples suggest that \( NV \) means “a limit of.” If \( NV \) is an integer this fits perfectly.]

\( 1 - 2/1\) in JBV; \(1 - 1/3\) in JBV;

\( 1 - 1/4\) in JBV; \(1 - 1/8^{10}\) in JBV;

\( \left(1 - \frac{1}{NV}\right)^{10} \) in JBV; \( NV \) JBV in JEV.

If \( NV \) means limit, then JEV contains the number \( e \), a verification of our guess that JEV named the real numbers.

The last two lessons: 30 and 31 were not published with the first twenty-nine because it made too long an exercise.

30. The later messages of this group have the mysterious sequences ABCD, ABCDE, DEFG, etc, each ending with STV. If we bunch these each as a unit, the messages parse. They then say JNV 1 natural number; JNV 2 natural number; JNV 3 natural number; JNV 123 STV natural number; conjecture STV means “the preceding is a set (or sequence),” and JNV means “belongs to.” There is doubt about the latter, since we thought earlier that it meant “contains”; AV belongs to 1234 = . AV is a natural number; 12345 or 4567 = 45 as sets; 12345 and 4567 = 1234567 as sets.

31. This last group is of impressive magnitude, 41 messages, of which the thirtieth is quite long. Parsing is eased by the parallel construction of the messages. They transcribe to:

- JRAV belongs to CHAV; JRBV belongs to CHAV; JRGV belongs to CHAV; the set JRAV, JRBV, JRCV, JRDV, JREV, JRFV, JRGV belongs to CHAV; [Since all the digits appear in these groups, maybe they are used like subscripts and should be read \( JR_1, JR_2, \ldots \), \( JO_1 \) belongs to CHAV; \( JO_2 \) belongs to CHAV; AV, belongs to CHAV; the set \( JO_1, JO_2, \ldots, JO_n \) belongs to CHAV; \( U_m \) and \( U_1 \) = 22 JO, belongs to CHAV. [This one must be parsed wrong or garbled]; AV, belongs to JR; BL, belongs to JR; BL, belongs to JR; BL, belongs to JR; AV < 3 and 12 > AV, \( \cdots \) BL, belongs to JR; AV, \( \cdots \) 13 and 22 > AV, \( \cdots \) BL, belongs to JR; AV < 23 and 44 > AV, \( \cdots \) BL, belongs to JR;
AV · 45 and 66 · AV · · · · · · · · · BL₁₁ belongs to JR₁;
AV · 67 and 126 · AV · · · · · · · · · BL₁₁ belongs to JR₂;
AV · 127 and 142 · AV · · · · · · · · · BL₁₁ belongs to JR₃;
The set BL₁₁, BL₂₁, BL₃₁, BL₄₁, BL₅₁, BL₆₁, BL₇₁ belongs to JO₁;
The set BL₁₂, BL₂₂, BL₃₂, BL₄₂, BL₅₂, BL₆₂, BL₇₂ belongs to JO₂;
The set BL₁₃, BL₂₃, BL₃₃, BL₄₃, BL₅₃, BL₆₃, BL₇₃ belongs to JO₃;
The set BL₁₄ and BL₂₄ and BL₃₄ and BL₄₄ belongs to JO₄;
The set BL₁₅, BL₂₅, BL₃₅, BL₄₅, BL₅₅, BL₆₅, BL₇₅ belongs to JO₅;
BL₁₆, BL₂₆, BL₃₆, BL₄₆, BL₅₆, BL₆₆, BL₇₆ belongs to JO₆;
BL₁₇, BL₂₇, BL₃₇, BL₄₇, BL₅₇, BL₆₇, BL₇₇ belongs to JO₇;
BL₁₈, BL₂₈, BL₃₈, BL₄₈, BL₅₈, BL₆₈, BL₇₈ belongs to JO₈;
BL₁₉, BL₂₉, BL₃₉, BL₄₉, BL₅₉, BL₆₉, BL₇₉ belongs to JO₉;
BL₁₀ and BL₂₀ and BL₃₀ and BL₄₀ and BL₅₀ and BL₆₀ and BL₇₀ belongs to JO₁₀;
The set BL₁₁, BL₂₁, BL₃₁, BL₄₁, BL₅₁, BL₆₁, BL₇₁ belongs to JO₁₁;
The set BL₁₂, BL₂₂, BL₃₂, BL₄₂, BL₅₂, BL₆₂, BL₇₂ belongs to JO₁₂;
The set BL₁₃, BL₂₃, BL₃₃, BL₄₃, BL₅₃, BL₆₃, BL₇₃ belongs to JO₁₃;
The set BL₁₄, BL₂₄, BL₃₄, BL₄₄, BL₅₄, BL₆₄, BL₇₄ belongs to JO₁₄;
The set BL₁₅, BL₂₅, BL₃₅, BL₄₅, BL₅₅, BL₆₅, BL₇₅ belongs to JO₁₅;
The set BL₁₆, BL₂₆, BL₃₆, BL₄₆, BL₅₆, BL₆₆, BL₇₆ belongs to JO₁₆;
The set BL₁₇, BL₂₇, BL₃₇, BL₄₇, BL₅₇, BL₆₇, BL₇₇ belongs to JO₁₇;
The set BL₁₈, BL₂₈, BL₃₈, BL₄₈, BL₅₈, BL₆₈, BL₇₈ belongs to JO₁₈;
The set BL₁₉, BL₂₉, BL₃₉, BL₄₉, BL₅₉, BL₆₉, BL₇₉ belongs to JO₁₉;
The set BL₁₀, BL₂₀, BL₃₀, BL₄₀, BL₅₀, BL₆₀, BL₇₀ belongs to JO₂₀;
CHAV belongs to KSPV.

The transcription leaves a lot to be resolved. There are several words
the meanings of which are yet to be determined. The word CHAV (or
CH₁) seems to be central. There are seven words JR₁ and eighteen
words JO₁ and each of these belongs to CHAV. There are 98 words BL₁,
each of which seems to belong to a unique JO. Does each also belong to a
unique JR? With this hint we can straighten out the garbled message
above; it reads "0<AV and AV<22 = · JO₁₁ belongs to CHAV";
there was a V omitted. I was also able to reparse six other messages.
I will not bore you with the details, since the list above has been
corrected.

Since each BL₁ belongs to one JR, and JO₁, these can be displayed in
a matrix

<table>
<thead>
<tr>
<th>JR₁</th>
<th>JR₂</th>
<th>JR₃</th>
<th>JR₄</th>
<th>JR₅</th>
<th>JR₆</th>
<th>JR₇</th>
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<tr>
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<td>BL₁₈</td>
<td>BL₁₉</td>
<td>BL₂₀</td>
<td>BL₂₁</td>
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<tr>
<td>JO₃</td>
<td>BL₂₃</td>
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<tr>
<td>JO₄</td>
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<td>BL₃₁</td>
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<td>BL₃₄</td>
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<tr>
<td>JO₅</td>
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<td>JO₆</td>
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<td>JO₁₀</td>
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</tr>
</tbody>
</table>
Remember that these are not decimal numbers. There is only one cell with more than one entry, and the subscripts in it in decimal notation are 21, 39, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98. The larger part of the entries is systematically distributed in the first eight rows. This suggests the periodic table of the chemical elements! On consulting a table we find, sure enough, that elements 57 through 71 are rare earths, and are lumped into one cell. Some, but not all, authorities also list 89 through 103 as rare earths. Elements 21 and 39 are Scandium and Yttrium.

CHAV must mean the periodic table. JR, means column x, and JO, means row y. BL2 means element Z. The meaning of KSPV is not known, except that it is a generalization of “periodic table.” It may merely mean table, or scientific fact, or university subject.

Looking back over the exercise we see we have penetrated the meaning of the basic symbols, and even more important, have learned some of the syntax rules of the notation, and have caught mistakes in the process. We have a few words for sophisticated concepts, and, given more data, with a little labor we could establish its translation.

The concepts used here are the basic ones of number, sets, and physical constants which any cultures must share. How bizarre the syntax and values of a culture could be I cannot conjecture, but any civilizations capable of sending a message across space must have many things in common.
APPENDIX

Recently a series of radio messages was heard coming from outer space. The transmission was not continuous, but cut by pauses into pieces which could be taken as units, for they were repeated over and over again. The pauses show here as punctuation. The various combinations have been represented by letters of the alphabet, so that the messages can be written down. Each message except the first is given here only once. The serial number of the message has been supplied for each reference.

1. ABCDEFGHIJKLMNOPQRSTUVWXYZ

2. AA B AAA C AAAA D AAAAA E AAAAAA F AAAAAAA G

3. LAA LBB LCC LDD LEE LFF LGG

4. LKBAA LCKBA LDKCA LDKBB LDKKC LEKDA LEKCB LEKCC LEKAD LFKEA LFKEB LFKCC LFKBD LFKEF

5. LFKAKBC LFKCKBA LGKAKB D LGKCAC LKABCKKABC

6. LAMBA LAMCA LAMCB LAMDA LAMDB LAMDC LAMDA LAMER LBMEC LAME

7. LMEMA LMHHA LMMCC LMDDD LMMEE LMMMFF LMMGG

8. LMAAA LMNAA LMOAB LMOBA LMOBB LMOBN LMBOB LFBOF LFBOG

9. LFEOABC LFUCOA LFUBCA LODEPQODEP

10. LBBB LBBBA LBBBC LBBBD LBBBE

11. LBBBKLJ LBBBKAG LBBBOND LBBBD

12. LBBBKLJ LBBBKAG LBBBCOND LBBBD

13. LBBBKLJ LBBBKAG LBBBCOND LBBBD

14. LBBBKLJ LBBBKAG LBBBCOND LBBBD

15. UAB UBC UCD UEJ UFJ UGJ UJBCRBCB

16. QJHA QLAC QLAKAA QLNOAA QLRBBB QUBB QHLLAB QQCC QUG

17. SLAA SUAB SLBKA SLAOAA SLNMAA SHLFOFLAPF SHLALAB

18. LATA LSTKATA LETKCTT LFTOCTT LCTG LANTJ

19. LABCTKOGJKBKORJAC LCBATKOCRJKBKORJAOARJN LDECTKOGKUXKEXKROFRJAOGRJN

20. HJLUHAY VAY HJLUHAYVAY HJLUHAYVAYVAY HJLUHAYVAYVAYVAY HJLUHAYVAYVAYVAYVAY HJLUHAYVAYVAYVAYVAYVAY

21. HJLUHAYVAYVAYVAYHJLUHAYVAYVAYVAYHJLUHAYVAYVAYVAYVAYHJLUHAYVAYVAYVAYVAY

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