STRATEGIES FOR COMMUNICATION WITH EXTRATERRESTRIAL CIVILIZATIONS

Communication is *much* less expensive than star travel. But still very problematic. Many choices to be made for "listening" strategy. We will discuss bandwidth, number of channels, sensitivity, etc. in class. Use "tuning the radio knob" analogy (discussed in class) to remember the problem.

WHERE TO POINT?

a. Search whole sky with low sensitivity -- could only detect strong signals.

b. Point at the nearest (less than about 50 to 100 l.y.) stars roughly like the sun and cooler (recall conditions for habitable planets). Could detect weaker signals, i.e. would have higher sensitivity.

c. Supernova announcement strategy (**not on exam**) -- point "downstream" from supernova if transmitting, or toward supernova if listening. Use supernovae partly because other civilizations are likely to be observing it. *But* this only gets civilizations along the line of sight, so low-probability.

SN 1987A in LMC: Messages should have arrived a few years ago.

WHAT FREQUENCY TO "LISTEN" TO OR SEND ON?

Interstellar dust selectively blocks shorter wavelengths (higher frequencies), which strongly suggests we use the IR or radio parts of the spectrum (long wavelengths or small frequencies).

For this reason we will discuss mainly radio searches; your text and Evans Ch. 9 have good discussions of this material, especially current searches, and your text has a good discussion of "Optical SETI" searches which are a viable alternative.

The other main consideration is **noise:** we should listen (or send) where the noise is minimized. (Figure discussed in class; surprisingly, not in your text! But in Evans Ch.9 reading)

a. Cosmic background radiation (3 K primeval cosmic background) -- important at low frequencies.

b. Receiver (quantum) noise -- increases at *high* frequencies.

c. Galactic noise (e.g. synchrotron radiation from SNRs) -- increases at *small* frequencies.

d. Earth's atmospheric noise. H_2O, O_2 emission bands, ...

Comes in above 10 GHz; but unimportant if broadcasting or listening from space.

This leaves frequencies between 1 and 10 GHz.

But the signal is likely to be in one or more *narrow* frequency bands (to get the strongest signal). Which frequency? Suggested "beacon frequencies" (or "hailing frequencies" or "magic frequencies"):

*HI (neutral hydrogen) 21cm (wavelength) line? Natural, abundant, but lots of interference by interstellar gas.

*OH line at 1.7 GHz?

*Inbetween H and OH? ("**The Waterhole**").

*Some frequency based on fundamental constants of nature?

*"Intergalactic" frequency standard based on temperature of cosmic background radiation?

Many others have been suggested.

● Or should we be searching in the infrared? >> **"Dyson spheres"** ("Type II civilization" based on energy utilization; consider how anthropomorphic, and so typical of Western science and consumer culture, it is to think that "advancement" must mean "being able to use more energy".) Students should understand why a Dyson sphere would give a characteristic signature in the spectrum of a star in a certain wavelength region. Text has good discussion of this, but fails to mention that many astronomical objects (e.g. old stars with circumstellar dust shells, dust in disks around protostars) have this signature, so there is no good way to distinguish Dyson spheres from natural phenomena.

● How about "**leakage radiation**?" This was discussed in detail in class. Your text points out that signal would be very weak because of spreading and inverse-square law of light, but we discussed why it might also be unrecognizable as a signal, mostly because of the confusion problem of so many radio and television stations broadcasting at once. Students should understand what the signature of leakage radiation would look like as a pattern in time.

● Some modern plans for searches concentrate not on detecting a signal that is a message, but a signal that is a sign of advanced technology. An example would be gamma rays given off by nuclear fusion reactions if they had starships that could utilize controlled nuclear fusion.

● What about signals from alien probes that are emitting signals (or leakage!) in our own solar system? Your text describes why searching at the "Lagrange points" might be a good strategy in this case.

Homework: Locate by an internet search a proposal to search for solar system probe signals or leakage by Bruce Cornet and Scot Stride from JPL using the Allen Telescope Array. Hint: A good interview with them is in the web magazine Astrobiology Magazine; a link to it is at the class web site. What objects to they propose to monitor? What seems to be the greatest uncertainty in the proposed search?

CODES

How to recognize an alien signal, or to send one that aliens would recognize? Most people think the problem is to devise a code that *any* other intelligence can decode.

The simplest and most efficient way to encode a message (we think) is *binary code*. Use only 2 characters, e.g. a 1 and a 0, or a + and a - , or "on" and "off", ... Each 1 or 0 (or whatever) is a "bit". Then the message can just be sent as a series of pulses.

Party line: expect the message to be a two-dimensional *picture* that is encoded in a one-dimensional binary string that factors into *prime numbers* .

e.g. 551 = 29 x 19 (or 19 x 29); 1679 = 23 x 73 (the 1974 Arecibo transmission).

Example: We receive signal 11111000001010110101 10101.
This factors into 5 x 5, giving a picture of the greek letter "pi".
Or try the letter "E", etc.

But why would ETI send out signals that *anyone* could decode? Perhaps they send out signals which could be understood only by others who are already "at the same level" as they are.

What would be a difficult signal for us to recognize? Example: recognizing a deterministic, high-dimensional (complex) pattern mixed with "noise" (probabilistic, stochastic, random process). Perhaps the test would be to recognize some sort of "meaning" in the message. (Think about musical signals. At present, there is no viable theory of musical meaning in music analysis, philosophy, cognitive science, pattern recognition, or any other field that has approached the problem. There is lots of (earth) music that most of us wouldn't even recognize as such [e.g. serial music of western composers (popular in 1950s-1970s), some music of other cultures])

A deeper examination of the issues involved here require a discussion of the nature of human languages. There are many important questions that are unanswered in this area, and have huge implications for SETI. Perhaps the most important concerns whether our kind of language is "hard-wired" into our brains, whether it is, at its root, universal, with the 1000s of world languages being merely surface manifestations of a more fundamental grammatical structure. This should remind you of the same question that arose in our discussion of intelligence (universalist or contextualist models).

[In order to keep the notes focused on SETI searches, I will put the material on the nature of language *after* the brief discussion of SETI searches in these notes. Hopefully we will have time to discuss these in class. The most interesting aspect for most people concerns whether and how severely language is affected by cognition (usually associated with "the Sapir-Whorf hypothesis" or "linguistic relativity," which is not taken very seriously in its strong form any longer, but still worth considering—see below).]

SEARCHES

Earliest search: 1960, Project Ozma.

"Cyclops"-- proposal to build 1000 100 meter telescopes, costing (at least) $10 billion; will probably never be built.

Several small programs using existing telescopes (e.g. Ohio State Univ.'s "Wow" signal).

Dec.1991: SETI funded at $100 million level by NASA. Details of search strategy discussed in Evans. 1994: Funding cut.

Now privately funded Project Phoenix, at SETI Institute is the largest search in progress; the associated "Allen Array" will be completed in 2005—see text. Also Project Meta, a few others. See text for an up-to-date discussion of the status of these projects. Students should investigate web sites at class web page on "SETI searches" for a tour of the different programs. I will expect that you're familiar with most of these (the most recent of which is the "Allen Telescope.")

Read Evans to understand what he calls "the cosmic haystack," which is a good way to visualize different kinds of search strategies. We'll discuss briefly in class.

NOTE: there will probably be no notes handed out for the topic of interstellar travel. Your text and Evans cover this in good detail, and I will cover some of the same material in class, but without handing out (or putting online) an outline of the lecture.

The Nature of Language—Implications for SETI

PROPERTIES OF HUMAN LANGUAGE
(Notice that this list is bound to be subjective)

 Uses ***representational symbols*** to stand for, or *represent*, something else–objects, places, actions, feelings,...

Not simply *signals* (as in most animal calls? e.g. warning calls) but *representations* of objects or actions.

Also, these symbols are *arbitrary* – most bear no similarity to the objects or actions they represent.

 Displacement – can talk about things not physically present in space and time (or even imagined things).

 Grammaticity – words can be sorted into different grammatical categories, e.g. nouns, verbs, adjectives, ...

grammar = rules of combination that *generate* acceptable (i.e. grammatical) strings or sentences and none of the ungrammatical ones.

Notice that a sentence can be grammatically correct but meaningless ("Colorless green ideas sleep furiously" is Chomsky's famous example) or grammatically incorrect but make sense ("This sentence no verb"). Are grammar and meaning really independent? What is "meaning"? etc.

 Knowledge of these rules is ***implicit*** – most native speakers cannot tell you what the rules are. e.g. phonetic rules when pluralizing nouns. [Ironic that implicit knowledge of grammar is so easily achieved by most people in childhood, yet modern *theories* of grammar are so complex that they take many years to learn. Telling us something?]

 Generativity – no limit to number of different sentences we can produce or understand. Even if only one kind of sentence, e.g. "Article noun verb article noun" ("The person threw the ball"), could still generate a large number of sentences. But we achieve much greater "generativity" by the use of

a. ***grammatical items*** (as opposed to "lexical items" that have some kind of demonstrable referent), that express relations (e.g. above,...before,...many), possibility (...can, might,...), contingency (unless, until, although,...), agency (by), purpose (for), necessity (must), existence (be–a wierd one!), nonexistence (no, none, not),... More than half of words in sentences are gr. items. Note how very abstract, conceptual, and unconscious these are! Also, why only small fraction of possible relations in the world grammaticized?

b. ***hierarchical*** (nested) structure:

phonemes – (15-70; e.g. *r*at, *b*at; *not* letters or graphemes)
——>morphemes – (smallest units of meaning, e.g. dog, -s,-ed, un- ,...)
——>words – (in English, about 10,000 speaking, 100,000 reading)
——>phrases ———> sentences

Is there a biological, human-specific, brain module or circuit for language? A "language organ"?(This is the underlying theme in much of the language development and cognition literature.)

1. ***Phases of development of language in children***

Apparently independent of social and economic conditions, cultures.

Suggests that neural "hookups" must be in place before succeeding steps occur.

But evidence now accumulating that *conceptual* development precedes language development; e.g. image schemas (notions derived from spatial structure, like container (in–out), trajectory, up–down,...See J.M. Mandler, *Amer. Scientist* vol.78, p.236, 1990), and "numerosity" (counting, adding,... in infants).

2. Vocal accents

Children in multilingual communities don't have detectable accents. All adults do. Suggests neural substratum already fixed early in life.

But there are a few contrary, mostly anecdotal, claims. And besides, aren't many things like this? If you don't learn it as a child, it's nearly impossible to become really proficient as an adult; e.g. riding a bicycle, swimming, playing a musical instrument. Most conventional theoretical linguists would *barf* at such a comparison, since we obviously aren't born with a bicycle-riding module.

3. ***Brain localization of language function***

* Broca's area, Wernicke's area
* Brain damage cases.

But when brain injury involving language areas occurs in young children, other parts of brain often take over, suggesting great *plasticity* , at least before ages 12-14 years.

Current work: PET, MRI —> language neural *circuits* (not so localized!) *But* also find neural circuits for *many* functions. Consider writing: suggests that major functional circuits can develop (evolve) *very* rapidly! What is the limit (if any)?

General implication of these 3 considerations: If biological substrate for language, then perhaps "uniquely human". But rather than its crowning achievement (traditional interpretation), this suggests that the human nervous system *limits* the interpretation of linguistic messages; humans may be *prohibited*, by the organization of their bodies and nervous systems, from learning certain concepts or types of concepts, or ways of "thinking" that do not even rely on "concepts".

But maybe our neural "circuits" are so plastic (modifiable) that we are capable of a wide range of (mostly unexplored) modes of thought, ***if*** we knew how to break our conditioning. Maybe an "advanced" alien civilization should be expected to have done so.

In either case, this suggests that finding *meaning* in an ETI message, once detected, may be the most formidable problem.

What else could be relevant to understanding of alien messages?

 Timescale – e.g. aliens with huge lifespans.

 Length – human ideas emerge at level of phrase or sentence. In human prose, length about 10-30 words. Could be much different?

 Discreteness – why a *discrete* pattern of *words* ? Maybe more continuous? (Think music.)

 Vocabulary size – aliens with much finer discriminatory perception, or much greater diversity in environmental conditions, or emotions, etc. Could have *huge* vocabulary (say, greater than a billion words, *if* words).

 If images, what kind of "meaning" is possible? (Consider "meaning" in visual arts)

 Arrangement – hierarchical structure is expected by most people, but that could be partly because we use such a structure (one of many antropomorphisms we have encountered). If this is correct, then maybe one could interpret an extraterrestrial hierarchical signal as "A complex cognitive entity is here." (Maybe not.)

Sapir-Whorf hypothesis – linguistic relativity and determinism.

"Language is not a way of expressing thought, but a mold that shapes our thoughts, that directs the particular way we perceive and structure the world." (Whorf) [Note: idea is very old– Heroditus, Neitzsche,...]

Really 2 propositions:

1. Linguistic relativity – there are differences in cognition associated with differences in language.

2. Linguistic determinism – language actually *causes* these differences.

Notice that extreme forms of linguistic relativity/determinism would have *serious* implications–"would close the door to objective knowledge once and for all."

Falling-out with academics, the discrediting, came in the 1960s due to: **a**. Rise of cognitive sciences, emphasizing commonality of human cognition; **b**. Piaget's school–universals of human development; **c.** Chomsky (1965) – case for language universals, computational theory; **d.** Developments in linguistic anthropology – discovery of universals in color cognition, ethnobotanical nomenclature, and (maybe) kinship terms.

More recent change in regard of Whorfian idea: shift toward relativism in many disciplines (esp. in anthropology; also "connectionism" in cognitive science and linguistics), more attention paid to differences.

Some evidence (pro and con) and problematic examples:

1. "Intertranslatability" – Can statement in one language be translated into a statement in another language? General consensus is "yes", although length may differ greatly. Argues against S-W. But a thought easily expressed in one language might never be expressed in another. (e.g. in Kiriwina language of New Guinea, "mokita" means "truth everybody knows but nobody speaks".)

2. Color terms and color cognition– Berlin and Kay's 1969 study (20 languages) supported cultural universality in color categorization and addition, despite huge differences in color terms. *But* color is something that depends primarily on peripheral sensory apparatus.

3. Noun/verb emphasis – Hopi; Navaho

4. Temporality – e.g. Hopi tenses (now generally discredited)

5. Gender markings – e.g. no gender markings for Chinese pronouns, etc., effects of forced reference to gender.

6. Interpersonal communication – Japanese, reduction of I/you distinction through precedence of social relationships over individual

7. Metaphorical nature of our whole conceptual system? (Lakoff and Johnson, *Metaphors We Live By*, e.g. "Time is money", "Argument is war",...)