Recently: The Drake Equation, Fermi Paradox, SETI.
Today: The Future of Human Civilization

Reading: As posted.
Homework #4 due today.
Final paper: Due Friday 11th May.
## Presentations and Papers

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The first National Academy of Sciences' conference on the search for extraterrestrial intelligence was held October 29 to November 3, 1961. In his opening remarks, Frank Drake presented the so-called 'Drake Equation,' which attempts to estimate the number of active, communicative civilizations in the galaxy. The equation is as follows:

\[ N = R_* \times f_p \times n_e \times f_l \times f_i \times f_c \times L \]

- \( R_* \): Rate of star formation in the galaxy.
- \( f_p \): Fraction of stars that have planetary systems.
- \( n_e \): Number of habitable planets in such systems.
- \( f_l \): Fraction of planets that are liquid.
- \( f_i \): Fraction that support life.
- \( f_c \): Fraction with detectable communication.
- \( L \): Average lifetime of the civilization.

The factors on the right are essentially unknown, so \( N \) remains a speculative estimate. Nevertheless, the Drake equations served, and still serves, as an excellent way to categorize our ignorance and thereby stimulate our understanding and research.
The Fermi Paradox according to Sherlock Holmes

“Is there any point to which you wish to draw my attention?”
“To the curious incident of the dog in the night-time."
“The dog did nothing in the night time.”
“That was the curious incident,” remarked Sherlock Holmes.

-- Silver Blaze, A. Conan Doyle
## SETI Conundrums

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A Famous SETI False Alarm (?)

The “Wow!” signal,
Jerry Ehman, Big Ear radio telescope, Ohio State 1977.
“Breakthrough Listen”

Stephen Hawking Joins Russian Entrepreneur’s Search for Alien Life

NY Times
20 July 2015
Who are we?

A mature civilization, like a mature individual, must ask itself this question. Is humanity defined by its divisions, its problems, its passing needs and trends? Or do we have a shared face, turned outward to the Universe?

In 1990, Voyager 1 swiveled its camera and captured the “Pale Blue Dot” — an image of Earth from six billion kilometers away. It was a mirror held up to our planet — home of water, life, and minds. A reminder that we share something precious and rare. But how rare, exactly? The only life? The only minds?

For the last half-century, small groups of scientists have listened valiantly for signs of life in the vast silence. But for government, academia, and industry, cosmic questions are astronomically far down the list of priorities. And that lengthens the odds of finding answers. It is hard enough to comb the Universe from the edge of the Milky Way; harder still from the edge of the public consciousness.
The Meaning of a SETI (Non-)Detection

There are qualitatively different scenarios:

1. No detection after comprehensive SETI.
   ➔ Conclusion: we are special in the sense of unique?

2. Detection of one or a few civilizations but the distance is large and there isn’t much information content.
   ➔ We are rare but not necessarily unique.

3. Detection of one or a few civilizations at relatively small distance (10s of light years).
   ➔ Communication is possible: exchange of information.

4. Detection of a large number of civilizations at varying distances with varying information content.
   ➔ We are neither rare nor unique.

What is the impact on our world view for each of these scenarios?
Suppose SETI fails after 10-20 years of intense searching?

• Does a null result mean anything? Is it science?
• What do you think a null result means for any of the possible ways in which we might detect ET?
  • N is small?
  • L is small?
  • ETs are quiet, introverted, don’t like to travel, are slow in traveling …
  • ETs have futuristic technology for communications, etc.
• “Any sufficiently advanced technology is indistinguishable from magic.” (A. C. Clarke)
**N = Number of Civilizations: big or small?**

\[ N = \text{astrophysics} \times \text{planets} \times \text{biology} \times \text{intelligence/technology} \times L \]

Or, more simply:

\[ N = \text{CFR} \times L \]

- CFR = Civilization formation rate

Is \( N \) dominated by the CFR or by L?

- CFR is large, L small \( \rightarrow \) N small.
- CFR is very small, L large \( \rightarrow \) N small.

The first case is pessimistic for us if we are typical.

The second case is good for us:

- Large longevity.
- Less risk of being invaded, perhaps.
THE FUTURE OF HUMAN CIVILIZATION

Reply hazy, try again later
… Each new discovery of an Earth-like planet in the habitable zone, such as Kepler-186f, makes it less plausible that there are simply no planets aside from Earth that might support life. The Great Filter is thus more likely to be lurking in the path between habitable planet and flourishing civilization.
How Human Beings Almost Vanished From Earth In 70,000 B.C.

Volcano  Toba supervolcano
Date      69,000–77,000 years ago
Type      Ultra Plinian
Location  Sumatra, Indonesia
          2.6845°N 98.8756°E
VEI       8.3
Impact    Most recent supereruption; plunged Earth into 6 years of volcanic winter, possibly causing a bottleneck in human evolution and significant changes to regional topography.
[1][dated info]
Implications of the Copernican principle for our future prospects

J. Richard Gott III

Making only the assumption that you are a random intelligent observer, limits for the total longevity of our species of 0.2 million to 8 million years can be derived at the 95% confidence level. Further consideration indicates that we are unlikely to colonize the Galaxy, and that we are likely to have a higher population than the median for intelligent species.

• Statistical argument for bound on $L$

• Basic idea has some validity; detailed statistical inference is incorrect; see article by Caves (2000)
Gott’s Conclusions

Homo sapiens:
\[ t_{\text{past}} \sim 200 \text{ kyr} \rightarrow 5 \text{ kyr} < t_{\text{future}} < 8 \text{ Myr} \]

“… we should not assume that our intelligence is likely to increase our longevity vastly above that of other species.”

… Do you agree?
Input to Longevity Estimation for calculations of N

Astrophysics: upper bounds on L for Earth.

• The sun will remain on the main sequence for another ~ 5 Gyr.
• The Earth will become too hot for most life from the increase in $L_\odot$ on a time scale of 0.5-1 Gyr.
• An NEO impact, nearby supernova or gamma-ray burst could lessen the likely L for *homo sapiens*.
  – A K-T type impact is due every few tens of Myr.
  – However … survivalist shelters?
Input to Longevity Estimation for calculations of N

Biology:
- No macroscopic predators.
- Direct kills from viruses/bacteria?
  Indirect via demise of the food chain?
  – Evolution marches on...
Astrobiology fights back:

• We’re invaded by ETs.

• Note that if $L$ is very large for a civilization that preceded ours significantly (up to 5 Gyr, say), then it is possible that the civilization will (or would have) colonize(d) the Galaxy on a time scale of (e.g.) a few $\times 100$ Myr.

• How plausible is this?

• Is space travel trivial or difficult?
Geology and environment:

- Global Warming and climate change. (Most obvious current challenge.)
- Overpopulation and civilizational collapse.
- Geological dangers: Yellowstone supervolcano; Cascadia Subduction Zone; ...
- Ocean current turn-off and sudden glaciation?
Input to Longevity Estimation
for calculations of N

Politics/culture:

• We kill ourselves off.
  – Is this even possible?
• Or we kill off all high-tech, electromagnetically loud activities.
• Or we revert to a laid back, low-tech, radio quiet lifestyle (like the dolphins).
• Or we continue on a high-tech track that happens to be radio quiet (electromagnetically quiet; also quiet in non-photonic activity).
  (e.g. cable TV, quantum communication.)
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A cause for optimism: the pace of technology
cortex selectivity activates only when imagining a main objective while performing related secondary tasks (84). Switching between unrelated tasks has no effect. Composite tool manufacture demands the planning and coordination of different kinds of subsidiary tasks and may have coevolved with this frontal lobe parallel processing module.

**Upper Paleolithic Technologies**

Although blade-based lithic technologies occurred throughout the MSA/MP (72–74, 85), more sophisticated ones appeared around 50 ka in East Africa and the Levant (85, 86). Blade production substantially increases the number of usable sharp edges that can be obtained from a core. Standard- 


d (74, 70). Bone, antler, and ivory are far less brittle than stone and make very reliable, durable armatures for projectile weapons (87). The spear thrower dramatically extended the power and velocity of a projectile, transforming a short-range attack weapon into a deadly missile. Traces of more perishable materials, including string and woven fibers that may have been made into nets, ropes, bags, and clothing are also well documented (88). These innovations are among many that signify modern human behavior, including art, ornamentation, symbolism, ritual burial, sophisticated architecture, land use planning, resource exploitation, and strategic social alliances, and may have originated in Africa during

**Conclusion**

The Oldowan and Acheulean industrial complexes are remarkable for their slow pace of progress between 2.5 and 0.3 Ma and for limited mobility and regional interaction. Distances of stone tool raw materials from their geological sources are rarely more than 10 km in the Oldowan and 20 km in the Acheulean (94), indicating very small home ranges. The proportions of materials originating from 40 to >300 km away increase during the late MP/MSA and early UP/LSA (95, 96), suggesting larger home ranges and regional interaction and exchange networks that could have facilitated long-distance population movements. Did the challenges posed by the increasingly variable, severe, and risky environments of glacial/interglacial cycles over the past 800,000 years (97–99), as well as more dramatic short-term climatic events (100), influence behavioral and biological evolution? Or were changes increasingly autocatalytic, driven by language and by cultural systems of knowledge and understanding of nature and society? With the appearance of near-modern brain size, anatomy, and perhaps of grammatical language ~0.3 Ma, the pace quickens exponentially, suggesting the latter. *Ex terra ad astra*: A mere 12,000 years separate the first bow and arrow (87) from the International Space Station.

**References and Notes**

3. W. C. McGrew, *Chimpanzee Material Culture* (Camb-
So What is in the Future?

- The Sun is heating up and so will the Earth.
- The Earth is spinning down (longer work week!).
- Asteroids and comets are lurking (NEOs).
- Major steps in our evolution?
  - Manage climate change and population.
  - Manage NEOs.
  - Further solar system exploration. Colonization?
  - Bionic and genetic evolution?
- Transformational concepts and technology:
  - String/brane theory and extra dimensions.
  - Quantum computing and teleportation.
- Further out: migration to nearby planets, tapping energy from other stars (including neutron stars, black holes?).
The full scale 10,000 Year Clock is now under construction. While there is no completion date scheduled, we do plan to open it to the public once it is ready. The essay below by Long Now board member Kevin Kelly discusses what we hope the Clock will be once complete. This is one of several projects by Long Now to creatively foster long-term thinking in the context of the next 10,000 years.

Clock in the Mountain
by Kevin Kelly

In 2001, The American Astronomy Society published a paper co-written by Danny Hillis that describes how the Clock reckons time over its 10,000-year design lifetime.
WHEN COMPUTERS EXCEED HUMAN INTELLIGENCE

THE AGE OF SPIRITUAL MACHINES

RAY KURZWEIL

AUTHOR OF THE AGE OF INTELLIGENT MACHINES

“The Age of Spiritual Machines will blow your mind. Kurzweil lays out a scenario that might seem like science fiction if it weren’t coming from a proven entrepreneur.”

— San Francisco Chronicle
The March of High Performance Computing
Would we understand an AGI?

• A true “Artificial General Intelligence” might have inscrutable (to us) motivations?

• Or … Paperclip maximizer?
  (Nick Bostrom, Ethical Issues in Advanced Artificial Intelligence, 2003).

*The AI does not hate you, nor does it love you, but you are made out of atoms which it can use for something else.*

—Eliezer Yudkowsky, Artificial Intelligence as a Positive and Negative Factor in Global Risk
Would we understand an AGI?

- A true “Artificial General Intelligence” might have inscrutable (to us) motivations?
- Contra: Lebowski theorem?

No superintelligent AI is going to bother with a task that is harder than hacking its reward function.

—Joscha Bach, Twitter

Cf. Principle of Least Effort.
IN THE GAME OF LIFE AND EVOLUTION THERE ARE THREE PLAYERS AT THE TABLE: HUMAN BEINGS, NATURE, AND MACHINES. I AM FIRMLY ON THE SIDE OF NATURE. BUT NATURE, I SUSPECT, IS ON THE SIDE OF THE MACHINES.
“… Consider again that dot. That's here. That's home. That's us. On it everyone you love, everyone you know, everyone you ever heard of, every human being who ever was, lived out their lives. The aggregate of our joy and suffering, thousands of confident religions, ideologies, and economic doctrines, every hunter and forager, every hero and coward, every creator and destroyer of civilization, every king and peasant, every young couple in love, every mother and father, hopeful child, inventor and explorer, every teacher of morals, every corrupt politician, every "superstar," every "supreme leader," every saint and sinner in the history of our species lived there – on a mote of dust suspended in a sunbeam. … There is perhaps no better demonstration of the folly of human conceits than this distant image of our tiny world. To me, it underscores our responsibility to deal more kindly with one another and to preserve and cherish the pale blue dot, the only home we’ve ever known.”
— Carl Sagan, "Pale Blue Dot"