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ET Might Write Not Radiate
Interference Avoidance, Pricing & Spectrum Management

- How good can that RF channel be? Really good!

Channel Quality

- Interference hurts ⇒ deal with it!

Delay Tolerant? Transmit when near base!

Infostations:

- Infostations redux (Infostations redux)

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DIMACS Series 3/24/04
RF Interference is bad
Storage density is increasing
Can tolerate delay
Channel good when nearby
Forget RF! Write message down! Toss it to recipient!

An Epiphany!
And maybe a LOT more room at the bottom

RNA: 3.6 × 10²⁴ bits/kg

STM with Xe on Ni: 1.74 × 10²² bits/kg

E-beam Lithography with SiO₂: 1.54 × 10²¹ bits/kg

Optical Lithography with SiO₂: 3.85 × 10¹⁸ bits/kg

A Little Empirical Rigor
A Little Analytic Rigor
\[(\Lambda)\eta \geq [(\Lambda)\eta] \mathcal{E}\]

If convex (Jensen):

\[[(\Lambda)\eta] \mathcal{E} = (\Lambda)\eta \max^\Lambda\]

If deterministic:

\[[(\Lambda)\eta] \mathcal{E} \leq (\Lambda)\eta \max^\Lambda\]

Max bigger than mean:
with equality iff \( \lambda(1) \) is constant

\[
\begin{align*}
\lambda y & \leq \left[ \left( (1) \lambda \right) y \right]^\lambda \min \left( \lambda \right) \leq \left( (1) \lambda \right) y^\lambda \min \left( \lambda \right) \max = \mathcal{E} \\
\end{align*}
\]

Jensen says

\[
\frac{1}{D} = \lambda \\
\]

subject to \( \lambda \)

\[
\left( (1) \lambda \right) y^\lambda \min \left( \lambda \right) \max = \mathcal{E} \\
\]

Minimum imparted energy

\[
\begin{align*}
\left( (1) \lambda \right) \mathcal{E} = \lambda = \frac{1}{D} = Tp(1) \lambda \int_{\lambda}^{1} \frac{1}{1} \\
\end{align*}
\]

Average velocity

\[
\text{Rocket Science} \\
\]

Where Not Radiate
\[
\frac{\gamma \mu \omega}{\lambda I} \approx \mathcal{E}
\]

\[
\left(1 - \frac{\gamma \left(\frac{c}{\omega} - 1\right)}{I}\right) \gamma \omega m = \mathcal{E}
\]

\[
\left(1 - \frac{\frac{\omega^2}{c^2} - 1}{I}\right) \gamma \omega m = (\Lambda)\eta \quad \bullet
\]

\[
(\Lambda)\eta = \mathcal{E}
\]

\[
\Delta \text{ and } (\Lambda)\eta \text{ GIVEN} \quad \bullet
\]

Minimum Transport Energy
\[ 0 = (x)_{,b} - (x)_{,b}x \]

\[ 0 = \frac{x}{\mathcal{E}} - \left( \frac{x}{\mathcal{E}} \right) \frac{p}{p} \]

\[ \text{Calculus of variations:} \]

\[ 1p(1)\mathcal{E} \int_{\frac{1}{2}}^{1} x \left( \min \max_{\text{min}} \right) \mathcal{E} = \mathcal{E} \]

\[ \text{Energy minimization:} \]

\[ ((1)x)b + ((1)\lambda)y = (1)\mathcal{E} \]

\[ \text{Potential energy:} (x)b \]
Non-relativistic:

\[ m \ddot{x} = q \times x \]

is force at position \( x \):

\( (x) \cdot p \)

\( \text{max} \)

Potential Field Results

Fictitious? \( \text{constant} = \langle 1 \rangle \cdot \mathcal{E} \text{ constant} \)

Freefall? \( \text{constant} = \langle 1 \rangle \cdot \mathcal{E} \text{ constant} \)

\( \text{Free fall} \leftarrow \text{force at position } x = \langle x \rangle \cdot \mathcal{E} \text{ constant} \)

\( \text{max} \)
Potential Field Results

- Low speed:
  - $q'(x)$ is force at position $x$: \( \rightarrow \text{"free fall"} \)
  - $E(t)$ constant $\rightarrow$ minimization satisfied with equality, so...
  - $\dot{m} \ddot{x} = q'(x)$
  - Freefall? $\rightarrow E(t)$ constant
Pay a factor of 2 over free space

\[ \frac{g^8}{2^{\sqrt{c^2}}} = \gamma \]

Delay at minimum energy

- \( g \ll 1 \) low speed
- \( g \approx 1 \) \( \sim \) near light speed

Let \( g = \frac{c^2}{D} \)

\[ \frac{c^2}{D} \]

Minimum energy

Artillery Problem
Escape Problem

- Milky Way: $v > 6 \times 10^7$
- Solar: $v > 7.1 \times 10^3$
- Earth: $v > 2.7 \times 10^4$

Escape examples (rough):

- Some energy penalty (but not a lot)
- Boils down to: need initial velocity larger than escape.
- Needs numerical calculation

Needs numerical calculation
We'll ignore relativity

Low speed ain't slow!

Off by only 10% at 0.4c and 50% at 0.75c

\[
\frac{d}{B} \approx \frac{\mu}{M}
\]

\[
\left(1 - \frac{v}{c}^2 \frac{\sqrt{1 - \frac{v^2}{c^2}}}{\sqrt{1 - \frac{1}{\sqrt{M}}}}\right) \frac{d}{B} = \frac{\mu}{M}
\]

General

Message size \( B \), mass information density \( \rho \)

Inscribed Matter Energy Requirements
\[ 1 + \frac{W^0\sqrt{\frac{4\pi D}{AC}}}{\nu} \ln 2 \geq 2 \left[ 1 - \frac{B}{W^L} \right] \frac{B}{W^L} \frac{4\pi D}{AC} = E' \]

Bits a la Shannon:

\[ \frac{4\pi D}{AC} \approx (D)^\wedge \]

Energy capture

Large TLW:

\[ 't_p = E' \]

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DIMACS Storage
\[
\left( \frac{2 \ln 2}{\Omega} \right) \left[ \frac{AV}{4nD} \right] \left[ \frac{\tau^2}{P_0 N} \right] < \Omega
\]

Large TW, \( \delta \ll 1 \)

\[
\frac{\ell_m}{\ell} = \Omega
\]

Definition:

\textbf{Radiation to Transport Energy Ratio}
No, inscriptional matter still wins!

\[
R = 10^6 \text{LY} \times 2.7 \times 10^{16} \text{stars} \quad \text{(but } N = 10^{32})
\]

\[
R = 10^4 \text{LY} \times 2.7 \times 10^{10} \text{stars} \quad \text{(but } N = 10^{28})
\]

Spherical galaxy, isotropic radiation, Arecibo-Arecibo

Milky Way stellar density 6.4 \times 10^{-3} \text{ stars (LY)}^{-3}

Radiation illuminates many → matter penalty

Is Radiation Better for Broadcast?
Construction energy not a problem

- $E^*$ at earth escape: $1.68 \times 10^{-17} \text{ J/bit}$
- $6.2 \times 10^{-17} \text{ J/bit}$ per ATP molecule
- $8 \times 10^{-20} \text{ ATP/second}$ for 20 minutes: 4639 Kbase of E-coli

Empirical energy calc:

- Landauer's said it can be reversible and arbitrarily fast

Matter Inscription/Readout Energy and Time

Does Inscription Energy/Speed Eat Budget?
\[ N \leftarrow 6666.0 = \Phi \]
\[ 000 = N \leftarrow 66.0 = \Phi \]

Now many repetitions optimally placed? \[ 1 \geq \Phi \geq 0 \] per year

Success criterion: \[ \Phi \geq 0 \]

Civilization Extinction Rate: \[ \beta = 1/10^8 \]

Civilization Birth Rate: \[ \alpha = 1/10^9 \]

Radiation Needs Repetition

Write Not Radiate
Delivery Methods

- Onward toward Lagrangian finge
- Probe (Bracewell)
- Embedded dust & rock (comet)?
- Dust?
- Big rock?
Delivery Methods (more detail)

- Need exhaust braking
- Energy penalty (excess mass): \( e \) 
- \( I_{sp} = \) Specific Impulse
  - Chemical: \( 10^2 \)
  - Nuclear Electric: \( 10^4 \)
  - Fusion: \( 10^6 \)
- \( I_{sp} = 20,000 \), \( \delta = 1000 \rightarrow \text{penalty} 4.6 \)
- \( \delta = 100 \) or \( I_{sp} = 2000 \rightarrow \text{penalty} 4.4 \times 10^6 \)
Cosmic Insults

Insults:
– High energy particle bombardment
– Heating (diffusion)
– Ion tracks, dislocations, subatomic cascades

Shielding:
– 10 million years at 10% bacteriaviability: 3 in radius rock
– 3.4 × 10^6 penalty
(36 cm^-3 density)

Clever Composition, Coding and Correction:
– Write Not Radiate

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DIMACS Storage 3/24/04
Inscribed matter messaging is not ridiculous

Inscribed matter messaging might often be preferred

Questions for storage types:
- General theory of inscribed matter storage?
- Composition and Coding for survivability?
- Ease of decoding (obviousness)?
- Inscribed matter messaging might often be PREFERRED

Inscribed matter messaging is NOT ridiculous

PUNCHLINES

http://www.winlab.rutgers.edu/~crose/cgi-bin/cosmic4.html

Learn more: