THE COSTS OF ENTROPY

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Continuing a passage that began several years ago, my wife and I recently sold our country home so that we could permanently retire in San Francisco. Given our advancing years, it was a reasonable but difficult decision. It was difficult because somehow in the process of closing down a long-time home, the residue of a lifetime was arrayed before us. We were confronted with either discarding or packing away the artifacts of our lives and careers, along with the other existential minutia we had collected through the years, which persisted in clinging to us like overly sheltered children.

As expected, the basement was the worst. My wife compared it to an archeological dig, each layer offering up a bit of our history, starting at the top with photos of a little calico cat that adopted us one rainy Valentine's Day, all the way down to the lowest strata which exposed a collection of Beatle phonograph records. But we made progress, and finally all that was left, hanging from a sturdy cross-beam, was my old Bianchi road bike. In the argot of the confirmed cyclist I had "hung it up" up many decades ago. Time and entropy had done their work well. The Bianchi's frame was covered with a gritty patina of dust, the seat and handlebar tape had sprouted mold, and the once bright spokes bore flakey scabs of rust.

The old bike had indeed succumbed to brother time and sister entropy, those twin deities of our transient universe. As I sat there looking at their work, it occurred to me that the feminine side of the pair is by far the more subtle and ubiquitously devious. Time announces himself from our conception and continues through our lives with a bass drum's well beaten cadence, measuring with metronomic precision our passing histories. But not so entropy; she is Chaos, she is Kali, she is Rust and Moth blowing down from the mountain top. And in those forms she goes about her work quietly, feasting on the fabric of our existence, the corrosion and cancer of what we are.

Although I had long been aware of what time had potentially allotted me, I rather belatedly came to recognize entropy's subtle powers. My first encounter with her was in graduate school at U.C. Berkeley in the spring of 1965. All first year political science graduate students were required to select one of several topics for what was then called a masters essay. Given a continuing interest in organization theory, I chose as my topic something which the department's faculty had rather ostentatiously entitled "the impact of computers and administration on organization and administration". With the enthusiasm of a first year graduate student, I went for the biggest gun in the rack – an un-choked double-barrel 10 gauge. With it, I didn't hope, I knew I could just about bring down every intellectual duck in Berkeley's turgid academic sky.

I doubt that I ever brought any ducks down, not that I really wanted to, and the grayness of the Berkeley skies darkened into the Free Speech Movement and the subsequent storms of the late 1960's. But, the hunting trip was successful – I eventually held in my hot little educated hand a piece of paper with Master of Arts written across the top. My masters essay was accepted, and more importantly I had had a formal but less than auspicious introduction to Ms. Entropy. No, it wasn't like a first date gone bad, and having her say:

"It was nice meeting you, and you really seem like a nice fellow, but now I'm really going to mess your life up big time."

No, my first meeting with entropy was a far more formal one, and although clandestine, was arranged by one of the librarians at the U.C. Doe Memorial Library. I met her as she hid deep in the darkened graduate research stacks, a smell of must pervaded the warm desiccated air, and from somewhere came the quiet moans of doctoral candidates whose faculty committees had been torn apart by political activism. She didn't say anything, but just pointed to a book on the shelf next to me. It was written by the mathematician and seminal cyberneticist, Norbert Wiener. As I leafed through the book's pages, Wiener immediately suggested that if I really wanted to know about entropy I should meet somebody named Claude.

"Who is Claude?", I wondered aloud.

"Why, of course, it's Claude Shannon who else could it be?", Wiener replied.

And, from there Norbert took me on a quick flight back to Bell Labs in 1948 where Dr. Shannon had just published a paper on the mathematical theory of communication. To some extent Claude had relied on Wiener's work on entropy, and that is probably why Norbert had led me to Bell Labs. Shannon's theory was not only elegant and operationally demonstrable, it was simple – it worked in the real world.

After we were introduced, but without preamble, Claude declared, "You must begin to think of information as being something that is subject to entropy".

"Ah", Norbert spoke up, "you're talking here about my friend Willie".

"Willie who?", I was forced to interrupt.

"Norbert is referring to Willard Gibbs." Shannon replied, "but first let me explain. In its simplest form my theory says we can think of something called 'informational entropy', and that we can use it as a measure of the uncertainty potentially inherent in a message – that is, it becomes a parameter by which we can gauge the effectiveness of any system of communication. The operational consequences here at Bell Labs is what we call the 'signal to noise' ratio. Something we have all experienced in graduate seminar rooms."

"Very funny", Norbert said, "but Claude I think it will help here for our young graduate student to understand that informational entropy is indeed a statistical measure of uncertainty. And, you see, that's where my friend Gibbs comes in. Gibbs took Maxwell's ideas on thermodynamics and said that any closed physical system will move toward a thermal equilibrium. To prevent stasis, you must keep the system open, and to keep the system open will cost you something. Such is life."

Then, rather strangely, Norbert's words trailed off into the shadows of the library stacks. Somewhere I heard an almost melodious woman's voice softly saying,

"Not a pretty picture if your universe is a closed system."

A year later I left Berkeley in 1966. Events from Viet Nam to the Free Speech Movement forced me to leave my metaphysical fantasies where I found them, resting along with Shannon, Wiener and Gibbs, deep in the library's graduate research stacks. Still, entropy's parting words rattled around in my mind, just below a level of consciousness which found itself increasingly devoted to the exigencies of making a living in the real world. Something I proceeded to do by learning

how to write FORTRAN computer programs, while working as a systems analyst at the University of California's popular new campus at Santa Cruz.

In its early years, U.C. Santa Cruz was a vibrant campus and, although the caste differences between faculty and "non-academics" such as myself were still much in evidence, the open intellectual environment at Santa Cruz fostered a sharing of ideas regardless of one's rung on the academic ladder. Frequently, I found myself discussing computer related questions with faculty members who had achieved a significant measure of intellectual and professional recognition, most notably George Herbig, David Huffman and Harry Huskey. Each in their own way helped me to know and deal with the realities of entropy.

I met George Herbig late one night. For some reason entropy had slapped me down, and I had dropped a deck of nearly a thousand punched cards on to the floor next to the Lick Observatory IBM 1620 computer, which had recently been moved to the campus from the observatory on Mt. Hamilton. George saw the devastation written on my face as I looked down at the now well randomized pile of what had once been a neatly sequenced FORTRAN program.

"Hi," George said, "wow, hope those cards have been sequenced-punched."

I shook my head negatively – I didn't even know what sequence-punching was. George explained that the reason why FORTRAN program code could not be entered in columns 73 through 80 of each punch card was because this was where we could put the sequence number of the card. So, if a deck of cards was dropped, it could be re-sorted by columns 73 through 80, and magically our FORTRAN program would be restored to its original in-line sequential order. What a concept. I thanked George and recommended that he be awarded the Nobel for what he just told me, along of course with his other work in astronomy.

It seemed like a waste of time, always a scarce resource for me, but from that point on I always sequence-punched my FORTRAN programs. Being both devious and clever, I knew entropy would test me again, as both David Huffman and I later jointly experienced.

David Huffman came to U.C. Santa Cruz from M.I.T.in 1967. As a graduate student, he had written a research paper on a theoretical method of coding information, now called "Huffman Codes", which has become a universal technique for managing informational entropy. David knew, as did George Herbig, the practical consequences of not controlling entropy. Unintendedly, early one morning in 1968 this was demonstrated to me first hand. I was sitting at one of the keypunch stations in the campus' new data entry room, punching up FORTRAN subroutines from coding sheets I had written the night before. A box of nearly two-thousand color-coded punched cards, representing a fairly large subroutine library, rested on the top of my work area. The box protruded slightly over the corner of the keypunch station, and as David rushed into the room, he accidentally hit the edge of the box. It was déjà vu all over again. Looking down at the brightly colored cards, thrown across the floor like a Jackson Pollock mural, the first words out of David's mouth were:

"Please, please, tell me they're sequenced punched."

They were and, for different reasons, from that point on David Huffman and I always had a mutual respect for each other.

Subsequently, over the years I learned that there was much more to controlling entropy than simply keeping punch cards in their proper sequence. I learned the importance of editing and

filtering input data – how to keep alphabetic characters out of numeric data items, to establish control balances for column upon column of ledger entries, to compute check digits for personal ID numbers – all of which was the expected canon to be known by those of us who would come to be anointed as “information technology professionals”.

So, somehow over the years, despite entropy’s best efforts, I evolved from a plodding journeyman systems analyst to an IT professional – or at least that was what I was called at university social gatherings. And, it was in that capacity in 1973 that I found myself in Rangoon as part of the United Nations Development Programme (UNDP), helping Burma install its first computer. I was there in support of a project jointly undertaken by the Burmese government, UNDP with its sister organization, UNESCO, and the University of California. I had been recruited into the project from U.C. Santa Cruz by Harry Huskey, who served as the project director.

Harry was one of those very rare individuals who could walk that narrow ridge between academic theory and everyday reality. Harry knew computers and he knew them beyond just the buzzwords of entropy, or Shannon information, or cybernetics. Working with Mauchly and Eckert on the original ENIAC, he had seen inside the heart of the machine, and I am honored to remember him both as a mentor and friend.

One warm night in Rangoon, having a curry dinner with Harry, we were discussing how the UNDP computer project was progressing. Among other responsibilities, I was teaching a post-graduate course in applied systems analysis. Harry asked me how it was going, and I mentioned that, contrary to legacy British academic practices, which many of the students expected, I was fairly successful at first presenting a number of case studies, and then providing the students with the integrative or unifying theory to which those practical examples were subject. This technique was especially successful when applied to data processing controls and the management of informational entropy.

“Did they have any trouble, then, understanding the concept of entropy in the context of Shannon’s theory?”, Harry asked.

“No, surprisingly not,” I replied with just bit of self-satisfaction.

“How about the cost of entropy”.

“Huh?”

Always the diplomat, Harry spared me from my ignorance by reminding me that, although it was then “the Socialist Republic of Burma”, the government there was just as committed to operational efficiency as we western capitalists.

“For this reason,” Harry continued, “*any time you talk about entropy, you must also consider not only the cost of its consequences*, *but also the cost of its control*. Remember when you told me about the time Huffman accidentally spilled the cards in your FORTRAN subroutine library? How much did that cost you – just the time you took to sequence-punch the cards – right? OK, so how much time would you have spent re-assembling the entire library deck, if the cards had not been sequence-punched.?”

Kindly offered that evening in Rangoon, Harry Huskey’s admonishment regarding the costs of entropy have remained with me. It has long outlived the era of punch cards and continues to be

applicable to the brutish jungle of today's Internet. The cost of maintaining a circular redundancy check or a pin-code still ensures the accuracy of a financial transaction, and to a degree protects against fraud and identity theft. The cost of that control is far less than the risk to our financial resources if it were absent. Sage professional advice from Harry Huskey that served me well throughout a long career in IT.

But in a broader sense, do any of us really understand the insidious impact of time and entropy in our daily lives? Over time we neglected a cleverly closed system – it was called the mortgage derivative market. Our leaders failed to control it, and in a classic Gibbsian response, massive external resources have been required, still without success, to deal with the resulting economic stasis. From a different quarter, the media reported during the recent American presidential debate that over 250,000 Internet "tweets" commented on one of the candidate's propensity to perspire. Unfortunately, the media left untouched what Claude Shannon might have thought about the resulting signal-to-noise ratio. And, as was so sadly shown to me as I looked down at my ancient rusted bicycle, entropy cleverly insinuates herself into each of our short times here, pulling apart the order we have tried to give it.

All of which leads me to remark that, lately, many of my friends seem a bit concerned about my continuing infatuation with entropy. Yes, it's true, sometimes as I lie awake at night waiting for sleep to come, I hear her whispering to me in that soft sweet voice:

"Not a pretty picture if your universe is a closed system."

But, then I drop off into the darkness of sleep.