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THE LONG FUTURE

If we are to survive through a long future, we must stay in contact with our long past.

--Freeman Dyson

FREEMAN Dyson is our foremost gazer into the future, and he likes to look long.

In his *Imagined Worlds* (1997) he uses Shakespeare's seven ages of man from *As You Like It* to outline a grand perspective of our possible futures. He sets the seven ages as "...not the seven parts of an individual life but the different time-scales on which our species has adapted to the demands of nature."

These scales are handily written in powers of ten: 10^x , where x runs from one to seven. At the upper end, ten million years, the major primates evolved.

Similarly, the best any deep time message across epochs can envision is communication to the last members of our species. This takes us to the scale of x between 6 and 7, when evolution may well find a different shape and portent for intelligence. For messages to survive beyond a million years demands that we place them beyond the reach of human intrusions and the rub of wind and water. This means launching them into the preserving vacuum of deep space.

Contemplating a message that could well outlast humanity itself is sobering, frustrating and exalting. On shorter scales there remain enormous difficulties. Our complexity as a thinking species arises in part from the inherent conflict between the contradictory demands of these time scales. We are geared to think on the scale of $x = 1$, a decade. Beyond that lies a full century, $x = 2$, the boundary of posterity. How to balance these?

In the future our crucial option will be whether we use our resources to continue our present, historically extraordinary two percent growth rate per year. There is no inherent physical reason not to expect that we will. Ambition is eternal. But to do so will enmesh us in severe crises of overpopulation and resource depletion. What sorts of "messages" can we transmit to our distant descendants in the language of the planet itself -- in biological and environmental information?

The future comes in all time scales, yet the cares of the day always win out over those of eternity. For example, in our unique age, growth dominates. Our population, economic resources, and sheer space packed with humans are all increasing by about two percent a year. Such population growth must end within a century, plausibly topping out at around ten billion souls.

Rather than struggles for land or riches, as in antiquity, Dyson argues that "The most serious conflicts of the next thousand years will probably be

biological battles." The human heritage itself could become the crucial issue. Yet in a way this is an optimistic view, for the next few centuries promise to strain the entire human prospect in unprecedented ways. Land and riches may still be the major driver in human affairs.

Here knowledge of and intuitions about deep time can be of help, perhaps crucially. Our modern sense of time's shadowy immensities should inform our own sense of our problems. Past methods of communicating across the ages had foibles and fatal delusions; ours do too, as I've described.

We should learn from these. Knowledge of history's panorama can aid our judgments today. Change accelerates all around us. We dwell in a unique epoch, hurtling downstream, borne by currents we can only weakly control. Only by sensing our place in the flow of time can we navigate the rapids ahead.

If we are not constrained to Earth's surface beyond the next century, our two percent growth rate per year would yield in a millennium a half-billion-fold increase in all these numbers. A message from the far past would be swallowed by such profusion, unless very carefully aimed at an audience that could not miss it. We have the examples of the pyramids and Stonehenge for strategies to achieve this: at a minimum, be big, solid, heavy, and hard to remove.

While our age offers harder materials and new locales, even the sanctuary of deep space may not remain distant in centuries to come. The uncountable numbers of lost messages should warn us that while our yearning for eternity will presumably persist, the attempt is not easy, and never certain.

How to penetrate such formidable barriers?

I asked a computer-whiz friend how he thought we could leave messages to the far future and he had a quick answer: "Scatter CDROM disks around. People will pick them up, wonder what they say, read them -- there you go."

After I stopped laughing, he said in a puzzled, offended tone, "Hey, it'll work. Digitizing is the wave of the future."

Actually, it's the wave of the present. This encounter was echoed by some of the Marker Panels members, making me think again of our present fascination with speed and compression as the paradigms of communication. (The nuclear waste burial site in New Mexico had assembled a Markers Panel to design monuments that could carry warnings of danger for ten thousand years. I served on the scenario-writing portion of the effort.) I imagined my own works, stored in some library vault for future scholars (if there are any) who care about such ephemera of the Late TwenCen. A rumped professor drags a cardboard box out of a dusty basement, and uncovers my collective works: hundreds of 3.5 inch floppy disks, ready to run on a DOS machine using WordPerfect 6.0.

Where does he go to get such a machine in 2094? Find such software? And if he carries the disks past some magnetic scanner while searching for these ancient artifacts, what happens to the carefully polished prose digitized on those

magnetic grains?

Ever since the Sumerians, we have gone for the flimsy, fast, and futuristic in communications; our fascination with the digital is only the latest manifestation. To the Sumerians, giving up clay tablets for ephemeral paper -- with its easily smudged marks, its vulnerability to fire and water and to recycling as a toilet aid -- would have seemed loony.

Yet paper prevailed over clay; while Moses wrote the commandments on stone, we get them on paper. Paper and now computers make information cheaper to buy, store, and transmit. Acid-free paper lasts about five hundred years, but CD-ROMs' laser-readable 0s and 1s peel away from their substrate within decades.

Music is probably the deepest method of communication across cultures. It speaks to our neural wiring, exciting pulses and rhythms that fit our mental architecture. The music of hunter-gatherer drums and pipes can instill in us feelings difficult to name but impossible to miss.

Until a few centuries ago, there was no method of preserving this most airy of communications. We do not know what tunes excited ancient Rome, though we have their instruments. Our modern sound recording promises new dimensions in directing durable meanings. Except for the Voyager disk, which sent songs, symphonies and shouts to the stars, this is a neglected theme in most deep time schemes; perhaps, given the speed of technological change, music is a more appropriate medium for the shorter scale of time capsules.

Still, music brings up a larger question: the mutability of all transcription, whether of the written or spoken word, or of song.

Consider the Babylonian cuneiform tablet. Many thousands of these clay bricks have come down to us, dried or fired, stamped with wedge-shaped pictographs. They are truly dead media, from the stylus to the language (Babylonian), to the very alphabet used. Only a few hundred scholars can read them. To a lesser extent, this also applies to a papyrus scroll and a Latin incunabula on medieval theology. Already, manuals for the Osborne computer have joined this company. Media and their messages fade from our world, sometimes with astonishing speed.

A desire for truly hard copy, preferably in stone, stems from its durability. Our modern digital libraries are more vulnerable than monastic scrolls were to a barbarian's torch; one power surge and all is lost.

Worse, nothing dates more quickly than computer equipment. Already historians cannot easily decipher the punch-card and tape technology of 1960s computers, and the output of early machines such as Univac are unintelligible.

Still, the future of long-term storage seems to belong to electronic media. The U.S. National Archives house about 6 billion documents, 7 million pictures, 19,000 movie reels and 200,000 recordings. The 165-acre Library of Congress, the world's largest library, houses about 120 million items and is adding about 5 million per year. But even acid-free paper is good for at most several

centuries, and few books are so well published today. (Indeed, the magazine you are reading will probably last only a few decades at best.)

Recordings fade, film dissolves, even museum-quality photos pale. People who work with these perishable mountains of yellowing print see electronic media such as CD-ROMs as their future. Even the Vatican's library, half a millennium old, is going digital.

In principle, digital is forever because it is easy to renew. Making exact copies is simple and costs much less than any other medium. But so far the burgeoning industry has not made a medium that can persist physically. Magnetic tape lasts a few years, videotape and magnetic disks at most a decade, and optical disks perhaps thirty years. So far, digital lasts forever or five years, whichever comes first.

Even if durable, digital media have an innate translation problem old-fashioned print does not. A document's meaning dissolves into a bit-stream of electronic zeroes and ones, meaningful only to the software that made it. Stored bits can represent text, a pixel dot in an image, an audio symbol, a number. There is no way to know which, or how to retrieve it, except by reading it with the proper software and hardware.

In just the last two decades, we have seen the quick-step march of mainframe computers, mini-computers, networks and soon, optical methods. Punch cards, computer tape, magnetic floppy disks, hard disks, optical storage -- what can a reader a century hence make of these? Future "cybraries" will have to contend with knowledge entombed in eight-track magnetic tapes, computer tape cartridges, analog videodiscs and compact disks, plus much to come. Even when translated to new media and software, material filtering through a new format is often distorted.

Imagine how the Iliad would read if the only existing text of the 2,400-year-old epic had been translated into every intermediate language between ancient Greek and modern English. How much of Homer's poetry and presence would survive? The multi-filtered text would be recognizable, but its essence, the spark and style and flavor of Homer, would be lost. Indeed, one might mistake it for a dry, longwinded history instead of a work of literature.

All this suggests that our recent passion for the digital is probably a passing fervor. Until it firms up into a standard method, transparent to many as text is today, with equipment that promises to survive a few human lifetimes, it seems an unpromising way to consign one's vital messages to the abyss of centuries.

Eventually, neither paper and CD-ROMs, nor any foreseeable computer-based method, are for eternity. Even tombstones blur, and languages themselves are mortal. How to talk across the ages, to call out a warning? How to get their attention, even? We have to learn to write largely, clearly, permanently. And largely may be most important of all, for the crowded human future may well drown out all but the most obvious voices, whispering of the distant past.

More deeply, how do we induce respect for whatever warnings we leave? Nobody will revere small, digital records, so the messages should be associated with larger, striking monuments. The Marker Panels seemed to me to want a very special response: not the grudging respect accorded an ancient threat, but a reflective consideration. Buildings of religious, emotional, or memorial impact tend to fare well. Cemeteries, for example, can hold their own against urban encroachment.

One of the striking images as one approaches Manhattan from LaGuardia airport is the broad burial grounds, still there after centuries despite being near some of the world's most valuable real estate. In Asia and Europe, temples and churches survive better than the vast stacks of stones erected to sing the praises of more worldly powers.

Of course, often they were better built, but also communities are hesitant about knocking them down. New religions often simply adopt the old sites. The Parthenon survived first as a temple to Athena, then as a Byzantine church, later a mosque, and now it stands as a hallowed monument to the grandeur of the vanished Greeks who made it.

Sometimes conquest destroys even holy places, as when the Romans in 70 A.D. erased the Temple of Solomon. Perhaps some conqueror thousands of years from now will pass by nuclear waste site warning monoliths. Seeing them as tributes to a society now vanquished, he might order them all knocked over, buried, their messages defaced.

Comparable events happened many times over as the Europeans moved across the planet a few hundred years ago, rubbing out the religious and literary past of whole peoples. The Mayans wrote on both paper and clay, but nearly all of their work is gone.

In this perspective, digital storage has a trump: make many copies, so even fanatics of the future cannot find them all. Scatter them. Leave the translating to an ingenious future, as all antiquity did. But will they?

In 1862 Victor Hugo had just published *Les Misérables* and while on holiday wanted to know how it was selling. He sent his publisher a note consisting of a single punctuation mark: ? Not to be outdone, the publisher replied with !. This was the shortest correspondence in history, and it is difficult to see how it could be equaled.

This worked because both sides knew from context enough to deduce much meaning from a single sign. Author Tor Norretranders calls this phenomenon exformation: content discarded but referred to by background and circumstances. Exformation can greatly compact messages. Alas, most contexts are present-saturated and quickly pass from the obvious to the unknowable. Who remembers the origin of "23-skiddoo," a "hep" expression of seventy-five years ago?

The Hugo-publisher correspondence avoided the perils of slang by using only punctuation. Still, it will mean nothing once English has altered or vanished,

so that ? and ! signify nothing except to scholars.

Exformation-rich messages have depth in the sense that they call forth much with few symbols. The more exformation shared by sender and receiver, the more compact a communication can be. The ultimate form is exformation carried by nothing, no information at all. Suppose I agree with you that I won't call by telephone tomorrow if everything is going according to some plan we have. If you hear nothing, you know you've learned something, with no signal passing between us. (Unless the telephones don't work, so I can deduce nothing.) Effortlessly, we have achieved the supreme compaction of communication.

Between friends this is simple, but alas, between distant eras and cultures it is nearly impossible. The only reliable exformation is that which we share as primates and humans: our way of filtering the world and our innate reactions to it.

What shall I build or write Against the fall of night?

--A.E. Housman

A visit to a Pleistocene cave in southern France reveals the past in subtle ways. Paintings on the cave walls and ceiling show a pack of wild horses galloping along a ledge, while vivid antlered reindeer leap toward the viewer from nearby walls. Bison scratched into stone show fine-line features of nostrils, eyes and hair. Big-bellied horses lope toward us on short legs.

These are not crude sketches. A big rocky bulge forms the muscular shoulder of a bison. A cow's body follows quite naturally a long, deep depression in one wall. Cleverly drawn animals blend, sharing a natural line in the wall. A ceiling frieze of small reindeer seem simply rendered under a flashlight's direct beam, but when the light angles away, the racks of their antlers follow the crests of slightly raised ridges in the rock.

Some prehistoric master saw the essence of these animals embedded in the chance curves of the cave. Then he called them forth to the eye, using negative space in ways we do not witness again until the work of the sixteenth century.

These signals across tens of millennia carry a heady sense of graceful intelligence. We know well enough what animals lived then, but only in such paintings can we delve into the cerebral wealth of our ancestors. Whether the artist intended them as such, these paintings then are the best sort of deep time messages, conveying wordless mastery and penetrating sensitivity across myriad millennia and staggeringly different cultures.

It is sobering to contemplate that our distant heirs may know us best not by our Michelangelos or Einsteins or Shakespeares, but by our waste markers, our messages aboard spacecraft, our signatures upon the soil and species, or our effect upon their landscape.

Yet that is a proposition we must entertain. The longest lived markers may be the damage we leave.

Only by trying varying perspectives can we hope to grasp how our culture may someday look to others vastly different, and perhaps better experienced.

Our time can benefit from the vistas made possible by science. When hatred and technology can slaughter millions in months, such terrors deprive life of that quality made scarce and most precious to the modern mind: meaning. Deep time in its panoramas redeems this lack, rendering the human prospect large and portentous again. We gain stature alongside such enormities.

Though I deplore the Kilroy Was Here impulse to mark the future with our scrawls, I realize that Kilroy's followers were expressing strongly felt emotions. Their gestures against the inevitable are merely futile, conveying little. Our names are surely the least aspect of our selves.

Considering our position in the long roll of epochs demands breadth transcending the momentary and the passingly personal. To reverse a famous saying of Newton's, I would hope that our grandchildren can fondly say of us, that if they have seen farther than our generation, it will be because they are standing taller.

Seeing farther goes with the territory of both science and science fiction.

Certain professions lend their followers an intuitive grasp of long duration. Archaeologists sense the rise and fall of civilizations by sifting through debris. They are intimately aware of how past societies mismanaged their surroundings and plunged down the slope of collapse, sometimes with startling speed.

Biologists track the extinction of whole genera, and in the random progressions of evolution feel the pace of change that looks beyond the level of mere species such as ours. Darwinism invokes cumulative changes that can act quickly on insects, while mammals take millions of decades to alter. Our own evolution has tuned our sense of probabilities to work within a narrow lifetime, blinding us to the slow sway of long biological time. This may well be why the theory of evolution came so recently; it conjures up spans beyond our intuition. On the creative scale of the great, slow, and blunt Darwinian wings such as we see in the fossil record, no human monument can sustain. But our neophyte species can now bring extinction to many, and that is forever.

In their careers, astronomers discern the grand gyre of worlds. But planning, building, flying, and analyzing one mission to the outer solar system commands the better part of a professional life. Future technologies beyond the chemical rocket may change this, but there are vaster spaces beckoning beyond which can still consume a career. A mission scientist invests the kernel of his most productive life in a single gesture toward the infinite.

Those who study stars blithely discuss stellar lifetimes encompassing billions of years. In measuring the phases of stellar mortality they employ the many examples, young and old, that hang in the sky. We see suns in snapshot, a tiny

sliver of their grand and gravid lives caught in our telescopes. Cosmologists peer at distant reddened galaxies and see them as they were before Earth existed. Observers measure the microwave emission that is relic radiation from the earliest detectable signal of the universe's hot birth. Studying this energetic emergence of all that we can know surely imbues (and perhaps afflicts) astronomers with a perception of how like mayflies we are.

No human enterprise can stand well in the glare of such wild perspectives. Perhaps this is why for some, science comes freighted with coldness, a foreboding implication that we are truly tiny and insignificant on the scale of such eternities. Yet as a species we are young, and promise much. We may come to be true denizens of deep time.

Though our destiny is forever unclear, surely if we persist for another millennium or two, we shall fracture into several species, as our grasp on our own genome tightens. We will dwell on the scale of a hastening evolution, then, seizing natural mechanisms and turning them to our own tasks. In this sense we will emerge as players in the drama of natural selection, as scriptwriters.

Our ancient migrations across Earth's surfaces have shaped us into "races" which cause no end of cultural trouble, and yet are trivial outcomes of local selection. Expansion into our solar system would exert selective pressure upon traits we can scarcely imagine now, adaptations to weightlessness, or lesser gravity, or other ranges of pressure or temperature. In this context, we will need long memories of what we have been, to keep a bedrock of certainty about what it means to be human. This is the work of deep time messages as well.

The larger astronomical scale too will beckon before us in such a distant era, for well within a millennium we will be able to launch probes to other stars. To ascend the steps of advanced engineering and enter upon the interstellar stage will portend much, introducing human values and perceptions into the theater of suns and solar systems. The essential dilemma of being human -- the contrast between the stellar near-immortalities we see in our night sky, and our own all-too-soon, solitary extinctions -- will be even more dramatically the stuff of everyday experience.

What changes might this presage? We could lend furious energies to the pursuit of immortality, or something approximating it. If today we eliminated all disease and degeneration, accidents alone would kill us within about 1500 years. Knowing this, would people who enjoyed such lifetimes nonetheless strive for risk-free worlds, hoping still to escape the shadow of time's erosions?

On the scale of millennia, threats and prospects alter vastly. Over a few thousand years, the odds are considerable that a large asteroid or comet will strike the Earth, obliterating civilization if not humanity. But within the next century, as our ability to survey the solar system and intervene there grows to maturity, we will be able to protect our planet (or even others) from such risks.

This marriage of space science and planetary protection will seem inevitable by

then, for it shall occur in the same era that we learn, perhaps by rudely administered punishments, to be true stewards of the planet. The impulse to do so will spring from a similar sense of the perspectives afforded, if we heed, by pondering deep time. A steward must look long.

We are ever restless, we hominids. It is difficult to see what would finally still our ambitions -- neither the stars, nor our individual deaths, would ultimately form a lasting barrier. The impulse to push further, to live longer, to journey farther -- and to leave messages for those who follow us, when we inevitably falter and fall -- these will perhaps be our most enduring features.

Still, we know that all our gestures at immortality -- as individuals or even as a lordly species shall persist at best for centuries or, with luck, a few millennia. Ultimately they shall fail.

Intelligence may even last to see the guttering out of the last smoldering red suns, many tens of billions of years hence. It may find a way to huddle closer to the dwindling sources of warmth in a universe that now seems to be ever-expanding, and cooling as it goes. Whether intelligence can persist against this final challenge, fighting the ebb tide of creeping entropy, we do not know.

But humans will have vanished long before such a distant waning. That is our tragedy. Knowing this, still we try, in our long twilight struggles against the fall of night. That is our peculiar glory.

Portions of this column appear also in Dr. Benford's new book, *Deep Time*. Comments and objections to this column are welcome. Please send them to Gregory Benford, Physics Department, Univ. Calif., Irvine, CA 92717. Email: gbenford@uci.edu