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NUCLEAR WASTE MANAGEMENT ORGANIZATION
SOCIÉTÉ DE GESTION DES DÉCHETS NUCLÉAIRES

NWMO BACKGROUND PAPERS
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Stewart Brand

NWMO Background Papers

NWMO has commissioned a series of background papers which present concepts and contextual information about the state of our knowledge on important topics related to the management of radioactive waste. The intent of these background papers is to provide input to defining possible approaches for the long-term management of used nuclear fuel and to contribute to an informed dialogue with the public and other stakeholders. The papers currently available are posted on NWMO's web site. Additional papers may be commissioned.

The topics of the background papers can be classified under the following broad headings:

1. **Guiding Concepts –** describe key concepts which can help guide an informed dialogue with the public and other stakeholders on the topic of radioactive waste management. They include perspectives on risk, security, the precautionary approach, adaptive management, traditional knowledge and sustainable development.
2. **Social and Ethical Dimensions** - provide perspectives on the social and ethical dimensions of radioactive waste management. They include background papers prepared for roundtable discussions.
3. **Health and Safety –** provide information on the status of relevant research, technologies, standards and procedures to reduce radiation and security risk associated with radioactive waste management.
4. **Science and Environment –** provide information on the current status of relevant research on ecosystem processes and environmental management issues. They include descriptions of the current efforts, as well as the status of research into our understanding of the biosphere and geosphere.
5. **Economic Factors** - provide insight into the economic factors and financial requirements for the long-term management of used nuclear fuel.
6. **Technical Methods** - provide general descriptions of the three methods for the long-term management of used nuclear fuel as defined in the NFWA, as well as other possible methods and related system requirements.
7. **Institutions and Governance** - outline the current relevant legal, administrative and institutional requirements that may be applicable to the long-term management of spent nuclear fuel in Canada, including legislation, regulations, guidelines, protocols, directives, policies and procedures of various jurisdictions.

<u>Thinking About Time</u>

The Clock of the Long Now – Selected Excerpts

Stewart Brand met with the Scenarios Team[1] in mid-2003 to share his thoughts about the concept of time, particularly thinking about very long time frames, and responsibility.

Many of the thoughts he expressed and discussed in that meeting are captured in his book <u>The Clock of the Long Now: Time and Responsibility</u>. At its heart is the question: "How do we make long-term thinking automatic and common instead of difficult and rare? How do we make the taking of long-term responsibility inevitable?" This question is explored through the attempt to design a clock that will operate for 10,000 years – a period of time equal to our lives on Earth since the last ice age. Five design principles emerged for such a clock: longevity; maintainability; transparency; evolvability; and scalability.

The Scenarios Team found Stewart Brand's ideas thought-provoking, both in attempting to visualize how our world might change over this very long timeframe (for instance look back at how our world has changed over the past several thousand years and multiply this to take into account the increasing rate of change we are experiencing,) and the kind of thinking which may be necessary now in order to be responsible to generations in the long future. Planning for the exercise of responsibility over such long time frames is one of the challenges we need to consider and address in identifying a used fuel management approach for Canada.

In order to capture some of the ideas expressed in this meeting, and to encourage thinking among all interested Canadians, following are selected excerpts from the GBN website; The Long Now Foundation website, and the book itself (Chapters 1 and 11), reprinted here with the permission of Stewart Brand.

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[1] *NWMO sponsored exercise to identify plausible future scenarios against which management approaches might be assessed*

“THE IDEA OF "THE LONG NOW," which comes from GBN member Brian Eno, is the idea of "the long view" plus inhabitation and responsibility. "Now" is the period of time in which we move with volition and a sense of the consequences of our actions—for most individuals about a week. A "nowadays" of decade length might be considered the field of action of a company dealing with the trends, lag-times, and lead-times of a large organization. "The long now," then, would stand for the time scale of civilizations—measured in centuries.” …

“Time and Responsibility. What a prime subject for vapid truisms and gaseous generalities adding up to the world’s most boring sermon. To spare us both, let me tie this discussion to a specific device, specific responsibility mechanisms, and specific problems and cases. The main problems might be stated, How do we make long-term thinking automatic and common instead of difficult and rare? How do we make the taking of long-term responsibility inevitable?

The device is a Clock, very big and very slow. For the purposes of this book it is strictly notional, a clock of the mind, an instrument for thinking about time in a different way. As it happens, such a Clock is in fact being built. The builders are finding that the very idea of the clock – why to build it, how to build it – forces their thinking in interesting directions; among other things, toward long-term responsibility. Since it works for them, please consider yourself one of the Clock’s builders. It won’t take long to catch up. Here’s a project summary from late 1998, complete with preamble:

> Civilization is revving itself into a pathologically short attention span. The trend might be coming from the acceleration of technology, the short-horizon perspective of market-driven economics, the next-election perspective of democracies, or the distractions of personal multitasking. All are on the increase. Some sort of balancing corrective to the short-sightedness is needed – some mechanism or myth that encourages the long view and the taking of long-term responsibility, where “the long term” is measured at least in centuries.
>
> What we propose is both a mechanism and a myth. It began with an observation and idea by computer designer Daniel Hillis …

Such a clock, if sufficiently impressive and well engineered, would embody deep time for people. It would be charismatic to visit, interesting to think about, and famous enough to become iconic in the public discourse. Ideally, it would do for thinking about time what the photographs of Earth from space have done for thinking about the environment. Such icons reframe the way people think. …

The Clock project became the Clock/Library with the realization of the need for content to go along with the long-term context provided by the Clock – a “library of the deep future, for the deep future.” The Clock/Library could take care of kinds of information deemed especially useful over long periods of time, such as minding extremely long-term scientific studies, or accumulating a Responsibility Record of policy decisions with long-term consequences. …

Whether or not a grand version of the clock eventually happens, the world continues to happen, and it happens to be in a new scale of trouble these days. Nobody can save the world, but any of us can help set in motion a self-saving world – if we are willing to engage the processes of centuries, because that is where the real power is. …

If you were going to design a clock to keep good time for 10,000 years, where would you begin? Danny Hillis started with certain design principles (that might apply to other things beside clocks, as does his whole approach of breaking down a problem into components and examining an exhaustive range of options). Invention comes at the end of this process, not at the beginning. The principles:

- Longevity: display correct time for ten millennia.
- Maintainability: with Bronze-Age technology, if need be.
- Transparency: obvious operational principles.
- Evolvability: improvable over time.
- Scalability: the same design should work from tabletop to monument size.

These principles led to a set of design strategies. Achieving longevity suggests: go slow; avoid sliding friction such as gears; avoid impacts such as ticking; stay clean; stay dry; expect bad weather, earthquakes, and human interaction; don't tempt thieves or vandals.

The principles of maintainability and transparency propose the use of familiar materials; make it easy to build spare parts; allow inspection; rehearse motions (so seldom-moving parts don't freeze up); expect restarts; and include the manual or be the manual – that is, build it so that everything is intuitively obvious.

For evolvability and scalability make all parts of similar size; provide a simple interface/readout; separate the functions – power, timing, calculation, and display.

Hillis analyzed each of these four functions in terms of what had been used in clocks before and what might be used now. For the power source water flow and wind are too damaging. Tidal power, plate tectonic, geothermal, chemical, and stored potential energy all scale badly. Atomic and solar electric power are difficult to maintain. Only temperatures change (such as a large bimetallic lever bent by the difference between day and night temperatures) and human winding survived the analysis. *Human winding* is the best candidate because it fosters responsibility (one purpose of the clock, after all) and invites people's involvement.

There are even more options for the timing mechanism. Too inaccurate: pendulum, water flow, solid material flow, spring and mass, wear or corrosion, ball roll, diffusion, audio oscillator, pressure chamber cycle, or inertial governor. Too unreliable: daily temperature cycle, seasonal temperature cycle, solar alignment (problematic clouds), or stellar alignment (clouds). Too difficult to measure: tidal forces, Earth's rotating inertial frame, or tectonic motion. Too high-tech and therefore difficult to maintain over a long time frame: piezoelectric oscillator (as in quartz watches), atomic oscillator.

The unsatisfactory conclusion of this analysis led Hillis to one of his Clock innovations. He would use an unreliable but accurate timer *(solar alignment)* to adjust an inaccurate but reliable timer *(pendulum),* creating a *phase-locked loop.* A Huygens (swinging) pendulum or torsional (rotating) pendulum would keep the Clock close to accurate, and then a pulse of focused sunlight at exact solar noon would adjust the Clock precisely on any day there was sun. In the event of prolonged cloudiness from volcanic eruptions, nuclear winters, or large meteor impacts, the Clock's pendulum could keep close-enough time for a few years until the Sun came out again.

A second major innovation emerged from analyzing the calculation options. Electronic calculation (as in digital clocks and watches) would be hopelessly invisible and difficult to maintain. The gears used universally in mechanical clocks wear down over time and offer only approximately correct ratios. A precomputed display requires too many calendar pages, hydraulic calculation requires too much power, and an array of levers requires too slow a timing source. This leaves only *mechanical digital logic.* If the Clock were a large, slow, mechanical computer, it would be as easy to understand as a geared clock – but far more accurate (because error does not accumulate in digital calculation the way it does in an analogue system of gears), and wear would not affect its accuracy.

The question of what temporal information the Clock would display and how such information would be displayed became a matter of much discussion. Each Millenial Clock would probably be somewhat different. Instead of multiple hands and faces Hillis opts for one face and one stationary "hand" with multiple concentric rings rotating under it. The rings could display the orbits of the visible planets (Mercury, Venus, Earth, Mars, Jupiter, and Saturn) and note the date according to the Chinese, Mayan, Jewish, Gregorian, and Islamic calendars. The rings could also predict solar and lunar eclipses for millenia to come. …"