Prospectus

for

Reversibility for Efficient Computing

(working title)

by

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1. Brief Description.

Reversibility for Efficient Computing will be a technical book, intended (1) to introduce the computer science and computer engineering community to the previously rather obscure topic of *reversible computing*, and (2) to educate the community about why reversible computing techniques will become increasingly vital for performance in both energy-limited (embedded/portable) applications and high-end supercomputing. The book provides within it the first ever analytical demonstration to show conclusively that reversibility is necessary for maximally-efficient large-scale computing. It is therefore well-positioned to become known as a seminal work, and to spawn an entire new area of computer science and engineering.

The book is in three parts. The first part is for theoreticians: it surveys the fundamental physics and computer science theory behind reversible computing, and presents our new arguments showing that reversibility is beneficial. The second part is for digital engineers: it shows how to design and build efficient reversible circuits. The third part is for computer architects and programmers: it introduces the reader to the design and programming of complete reversible processors. (A web-distributed supplement provides technical data: circuit diagrams, programming language specifications, simulators, compilers, sample programs, etc.) Each part assumes only that the reader is an educated professional in the relevant area (theory, engineering, programming). We do not assume any past familiarity with reversible computing concepts. We review all the relevant previous work, and provide numerous references for the scholar who wishes to delve into it in more depth.

2. Outstanding Features of the work:

- Well written: self-contained, well-organized, numerous figures and examples, good prose, well-explained.
- Techically sound and complete, contains detailed mathematical explications of ground-breaking new theoretical results of practical importance.
- Applauded by past MIT press authors Thomas Knight, Norman Margolus, and Gerald Sussman.
- Saleable to numerous audiences: computer science theorists, device physicists, digital engineers, computer architects, and algorithm designers.
- Potential to become a seminal work, starting new directions in computing.

3. Competition.

Reversible computing has previously been an obscure topic, so there are no existing books that we know of that contain comprehensive, up-to-date discussions of the topic. Our book is really the first to convincingly demonstrate that reversible computing warrants great interest from the wider computing community. So we expect that if this book were widely promoted, it would stir up a surge of new interest in this topic, and new competition. But we will probably remain two of the world's most knowledgeable authorities on this topic for some time. Here are particular books we know of that mention reversible computing. None focus entirely on it.

- Feynman and Computation (Perseus Books, 1999) - a collection of papers, many by reversible computing researchers. Contains some good background material for our book (we reference it).
- Feynman Lectures on Computation (Addison-Wesley, 1996) - contains a chapter on basic reversible computing concepts.
- Unconventional Models of Computation (Springer, 1998) - A conference proceedings containing several papers on reversible computing by our group.
- Maxwell's demon: entropy, information, computing (Princeton University Press, 1990). Collection of papers, some relating to the basic thermodynamics background for reversible computing.
- Cellular Automata Machines (MIT Press, 1991) contains some discussion of reversible cellular automata models of physics, but does not really advocate physically reversible computers per se.
- Proceedings of the Workshop on Physics and Computation (IEEE Computer Society Press, 1992 and 1994, and New England Complex Systems Institute, 1996). These 3 conference proceedings contain some reversible computing papers.

4. Apparatus.

a. The book will include extensive references, and numerous figures. Appendices will give programming documentation, and detailed mathematical derivations.

b. There will be supplementary appendices (suggested distribution: on the web) that provide working program code examples, complete circuit schematics, etc.

5. Audience.

a. The book is intended for advanced students, academic researchers, and industry professionals.

b. Disciplines: computer science theory, digital electrical engineering, computer systems design, supercomputing.

c. The book contains substantial amounts of mathematical & quantitative analysis, but the important points can be understood by reading the descriptive text. The book contains both rigorous and informal arguments.

d. A familiarity with the basic principles of physics, computer science theory, digital engineering, and programming is helpful. However, a reader not familiar with one of these areas can skip the part of the book having to do with that area, and still learn useful information from other parts.

As for the mathematics, a slight amount of calculus and set theory is used. But most of the book does not require any mathematical tools more advanced than basic algebra.

6. Market Considerations.

What kind of person will by the book, and why?

- A computing professional interested in understanding how to design future computing systems that are as efficient as possible.

- An applied physics researcher who wants to understand the requirements for future generations of extremely small computing devices.

What new information will the book give them to justify its cost?

- It will show them exactly why reversible computing principles will be increasingly vital for high-performance computing.

- It will introduce them to the design of reversible circuits, processors, and algorithms, and show them that reversible design is not difficult.

What is your estimate of the total market for the book?

- Tens of thousands of computing professionals, world-wide.

Professional organizations or mailing lists that might be useful in promoting the book:

- IEEE.
- ACM.
- Physics of Computation mailing list (maintained by nhm@im.lcs.mit.edu).

7. **Status of the Book.**

a. The book will essentially be a consolidation of two Ph.D. theses, which have already been written. All that is needed is the integration of material from the smaller thesis into the framework of the larger one.

b. A manuscript of the larger thesis (which reads much like the final book will) is already available, and could be sent out to readers, possibly together with the smaller thesis. Full integration of the two theses should take about a month of additional work.

c. Planned length is about 450 pages, plus supplementary material on the web.

d. There will be about 100 figures, and about 32 tables of data.

8. **Reviewers.**

Here are some suggested reviewers (and affiliation/specialty):
- Charles H. Bennett (IBM Research, quantum information).
- F. Thomson Leighton (MIT LCS, VLSI theory)
- Charles Leiserson (MIT LCS, parallel algorithms)
- Anantha Chandrakasan (MIT EECS, low-power computing)
- William Athas (USC/ISI, energy-recovery circuits)
- Ralph Merkle (Xerox PARC, nanotechnology)
- Tom Toffoli (Boston University, complex systems)

Anonymous submission is not necessary.