Long-term efficiency growth for arbitrary computations requires this new paradigm

**Problem**

- CMOS roadmap is nearing fundamental thermodynamic limits to energy efficiency of all conventional computing
- Improving practical supercomputer performance beyond exaflop scale will require a new computing paradigm

Fundamental physical law supports just one general solution...

**Approach**

- **Landauer’s Limit** (1961): A rigorous consequence of fundamental physics!
- **Reversible Computing**: (Landauer, Bennett) The only way around that limit—lets us keep improving energy efficiency with no known limit.
- **Adiabatic Circuits**: Allow implementing reversible computing using ordinary switches (e.g., MOSFETs).
- **Asynchronous Ballistic Reversible Computing**: A novel implementation concept designed to improve speed and reduce overheads compared to existing synchronous adiabatic approaches to reversible computing

**Results**

- My major contributions to this field since 1996:
  - Systems scale better asymptotically with reversible computing in physically-realistic models
  - Defined principles of fully-adiabatic circuits, improved design and simulation methods
  - Detailed design work towards practical chips including detailed simulations and new resonator concepts
  - Major new advances since arriving at Sandia in 2015:
    - Core reversible computing theory generalized
    - Novel clockless models for reversible computing

**Significance**

- Energy efficiency of arbitrary computations can increase without any known limit as technology is refined
- However, progressing very far beyond the present thermal roadblocks requires we move to this new paradigm of reversible computing.
- Near-term, properly designed adiabatic chips could demonstrate 10–100x energy efficiency benefits, boosting the aggregate performance achievable in power-limited HPC applications
- Long-term, new reversible technologies beyond the limits of adiabatic CMOS will be needed; a new LDRD effort is starting in this area

**This work substantially contributes to Sandia’s ongoing leadership in future high-performance computing**