Reversible Computing
The Answer to Scaling

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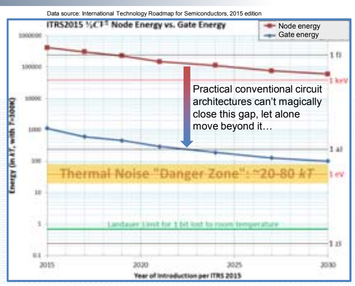
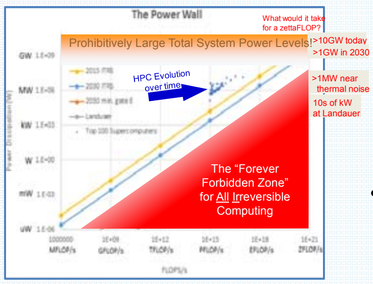
Long-term efficiency growth for arbitrary computations requires this new paradigm

Problem

- CMOS roadmap is nearing fundamental thermodynamic limits to energy efficiency of all conventional computing



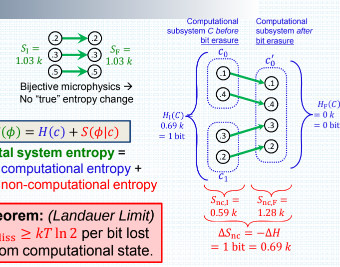
- Improving practical supercomputer performance beyond exaflop scale will require a new computing paradigm



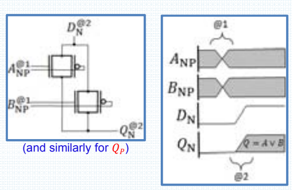
Fundamental physical law supports **just one** *general* solution…

Approach

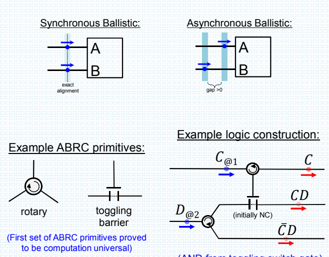
- ***Landauer's Limit*** (1961): A rigorous consequence of fundamental physics!
- ***Reversible Computing:*** (Landauer, Bennett) The only way around that limit—lets us keep improving energy efficiency **with no known limit.**



- ***Adiabatic Circuits:*** Allow implementing reversible computing using ordinary switches (*e.g.*, MOSFETs).

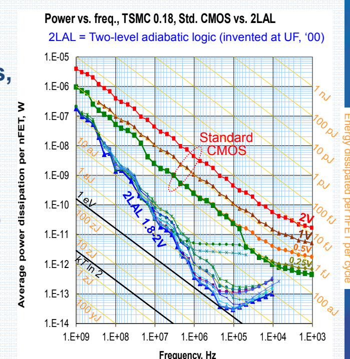


- ***Asynchronous Ballistic Reversible Computing:*** A novel implementation concept designed to improve speed and reduce overheads compared to existing synchronous adiabatic approaches to reversible computing



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

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