Frontiers of Extreme Computing 2007 Zettaflops Workshop

Erik P. DeBenedictis

Acknowledgements

- **David Womble to introduce workshop**
  - **Thank Erik DeBenedictis for being general chair**
  - **Thank Thomas Sterling for being deputy chair and also for developing the Petaflops workshops 1994 onward**
  - **Thank Horst for also founding of Zettaflops**
  - **Acknowledge Sandia/CSRI for producing the workshop**
  - **Thank organizing committee**
    - **In alphabetical order, Bill Camp, Candy Culhane, Mike Foster, Jag Shah, Horst Simon, Rick Stevens, Tom Theis, Stan Wiliams, David Womble**
  - **Thank financial contributors**
    - **In order of contribution, Sandia, HP, Intel, DOE/Sc, DARPA, LBL, Cray**
  - **Thank Caltech for hosting the Website**
  - **Thank Yeen Mankin of LBL and Deanna Ceballos and Bernadette Watts of Sandia for their support**
  - **Thank speakers and group leads for their extra effort**
  - **Thank all participants for expending the effort of travel and their time and assure them that we hope to give them a positive return**
  - **Thank Thomas Sterling in advance for writing the monograph**
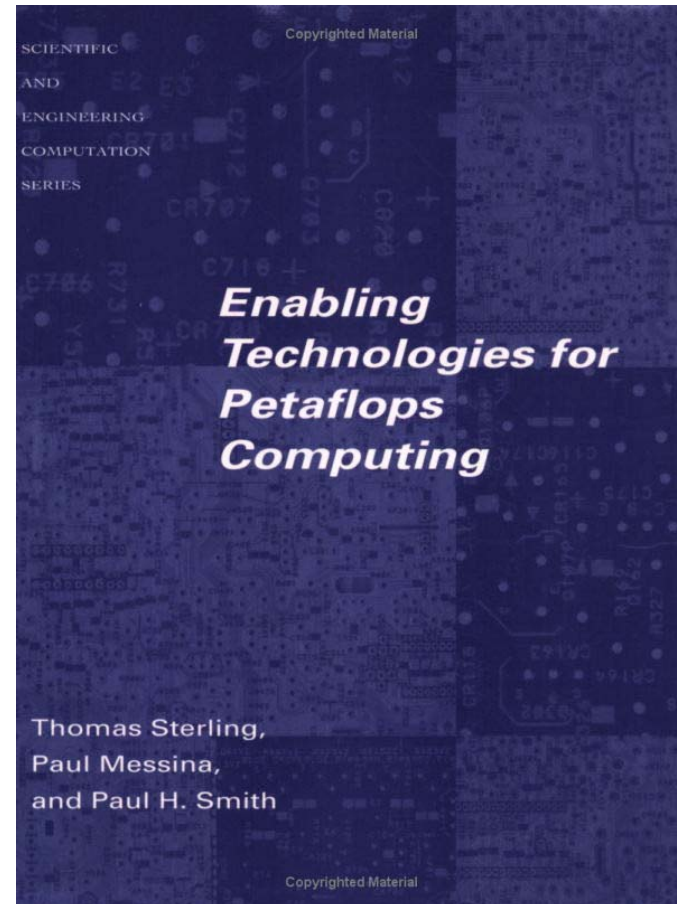
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History

History and Book

- 1994 Petaflops I, Pasadena
- 1999 Petaflops II, Santa Barbara
- 2002 WIMPS, Bodega Bay
- 2005 Zettaflops, Santa Cruz
- 2007 Zettaflops, Santa Cruz

- [Note: there were other activities]

SCIENTIFIC AND ENGINEERING COMPUTATION SERIES

Enabling Technologies for Petaflops Computing

Thomas Sterling, Paul Messina, and Paul H. Smith

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Petaflops/Zettaflops Format

- **These are interdisciplinary workshops on computation in the future**
  - **Technology is best sold for the benefit of its use to society**
    - **This is an objective of the workshop**
  - **We assemble people representing the self-organized "technology stack" that benefits society through computation, reinforcing our team**

From Petaflops Workshop 1994

- **The objectives of the [1994] workshop were to:**
  - **Identify applications that require PetaFLOPS performance and determine their resource demands**
  - **Determine the scope of the technical challenge to achieving effective PetaFLOPS computing**
  - **Identify critical enabling technologies that lead to PetaFLOPS computing capability**
  - **Establish key research issues**
  - **Recommend elements of a near-term research agenda**

Continuity and Changes
Petaflops (94→03) to Zettaflops (04→07)

- We all lived out the last decade, buying ever faster PCs
- A decade ago, the vision of computation was limited by our imagination because the technology was set to grow exponentially in power over time (Moore's Law)
- Moore's Law delivered easy-to-exploit clock rate increases, as well as density increases

- In this workshop, we will see somewhat of a reversal
- Moore's Law delivers through more parallelism
- We will see compelling applications that exceed the ability of technology to execute
- Thus, we have this workshop to organize efforts to improve the technology

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What Can We Accomplish?
(Erik's Suggestion, need you help)

What Can We Accomplish?
(Erik's Suggestion, need you help)

- **We have a unique group**
  - **Broader: Devices through applications**
- **There are several post-petaflops initiatives approaching Congress**
  - **Note: I will recommend broadening beyond FLOPS**
- **Zettaflops is not a part of any such initiative, but we are funded by DOE, DARPA, and have participation by several other Government agencies, and industry**

- **Action: Leverage our unique breadth by thinking through the key, broad cross-cutting issue of the day**
- **See if we can support one or more of the advanced computing initiatives, increasing the likelihood of their getting funded**
- **The cross-cutting issue: how much value to society will result from different computational technology investments**
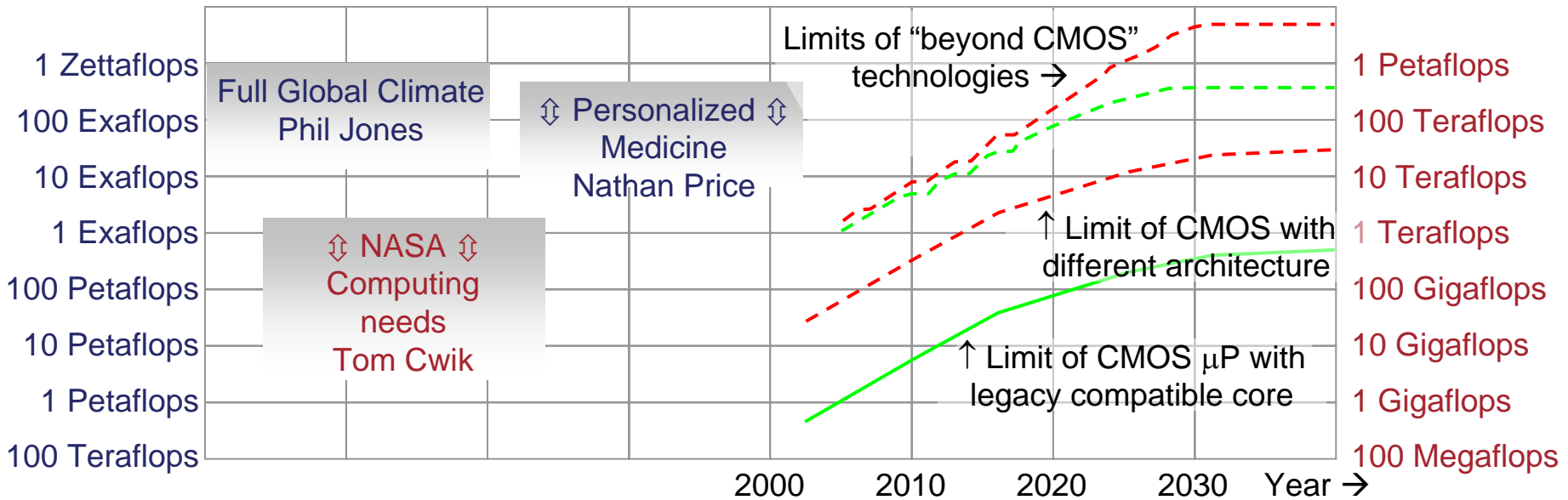
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Objective of Workshop: Fill In Blanks Here

Supercomputer Performance (5 MW) | Applications | Technology | **Mobile Performance (5 W)**

Supercomputer		Mobile
1 Zettaflops		1 Petaflops
100 Exaflops		100 Teraflops
10 Exaflops		10 Teraflops
1 Exaflops		1 Teraflops
100 Petaflops		100 Gigaflops
10 Petaflops		10 Gigaflops
1 Petaflops		1 Gigaflops
100 Teraflops		100 Megaflops

Full Global Climate
Phil Jones

⇕ Personalized ⇕
Medicine
Nathan Price

⇕ NASA ⇕
Computing
needs
Tom Cwik

Limits of "beyond CMOS" technologies →

↑ Limit of CMOS with different architecture

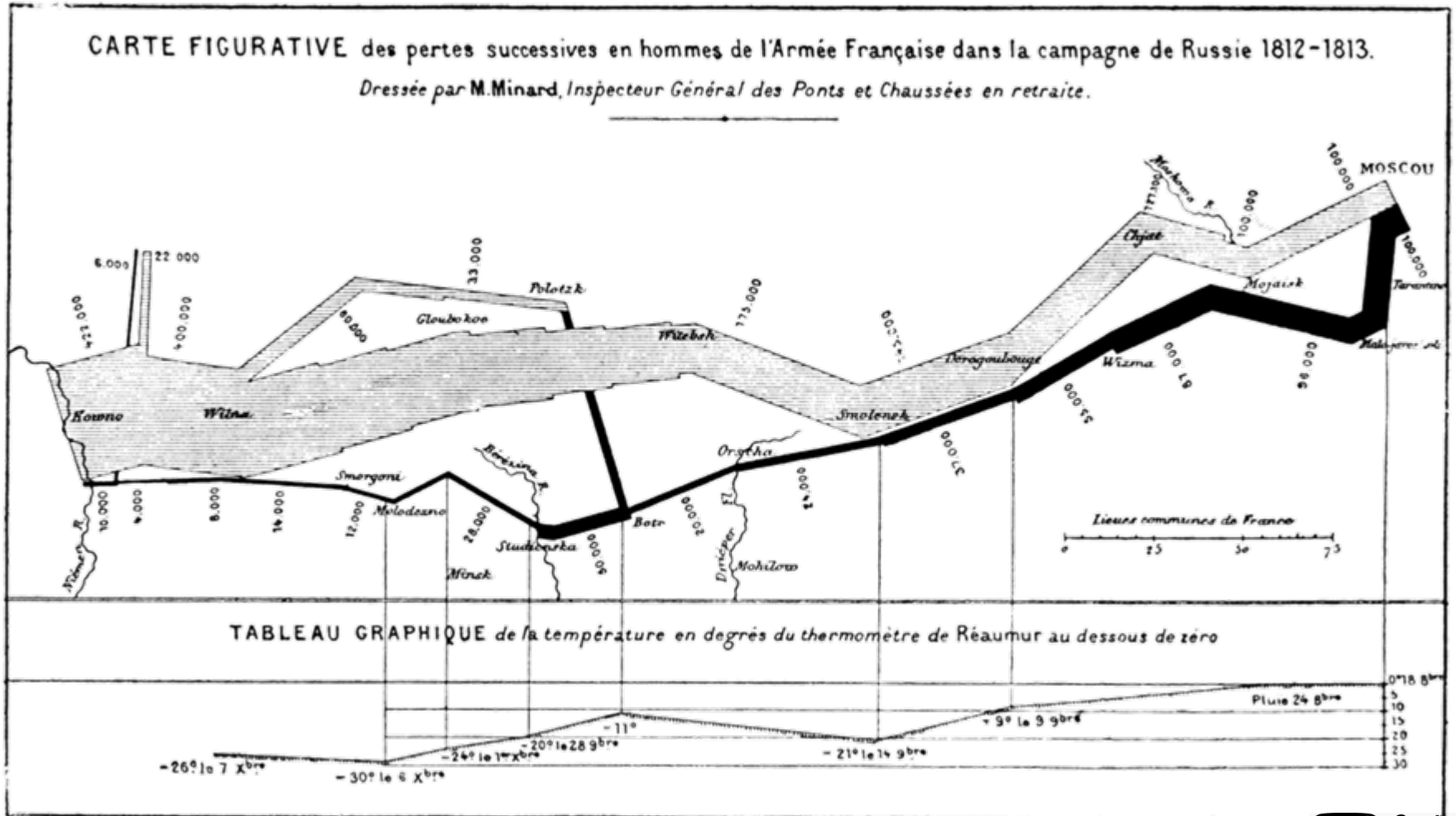↑ Limit of CMOS μP with legacy compatible core

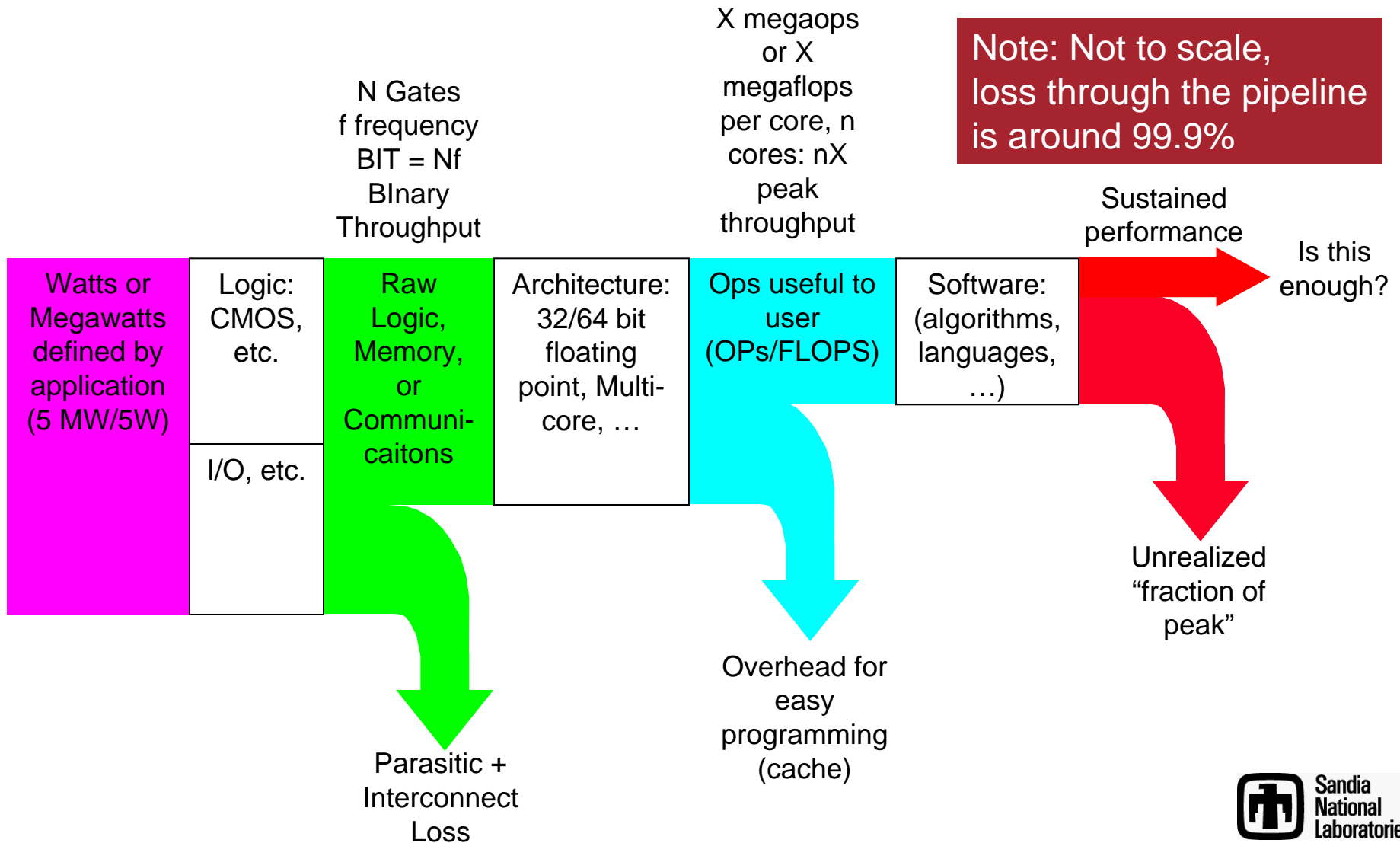2000   2010   2020   2030   Year →

Erik's Suggestion for Workshop Output

- **Make proposals for short, medium, long term computation**
- **Suggest applications, software, architecture, and technology that everybody believes is feasible for each timeframe**
- **Such that the technology's capabilities fit the application's requirements**
- **This would appear to be a unique contribution ??**

The March to Moscow and Back

CARTE FIGURATIVE des pertes successives en hommes de l'Armée Française dans la campagne de Russie 1812-1813.

Dressée par M.Minard, Inspecteur Général des Ponts et Chaussées en retraite.

TABLEAU GRAPHIQUE de la température en degrés du thermomètre de Réaumur au dessous de zéro

The March to an Application

X megaops or X megaflops per core, n cores: nX peak throughput

N Gates
f frequency
BIT = Nf
BInary
Throughput

Note: Not to scale, loss through the pipeline is around 99.9%

Sustained performance

Is this enough?

| Watts or Megawatts defined by application (5 MW/5W) | Logic: CMOS, etc. | Raw Logic, Memory, or Communi-caitons | Architecture: 32/64 bit floating point, Multi-core, … | Ops useful to user (OPs/FLOPS) | Software: (algorithms, languages, …) | |
| | I/O, etc. | | | | | |

Parasitic + Interconnect Loss

Overhead for easy programming (cache)

Unrealized "fraction of peak"

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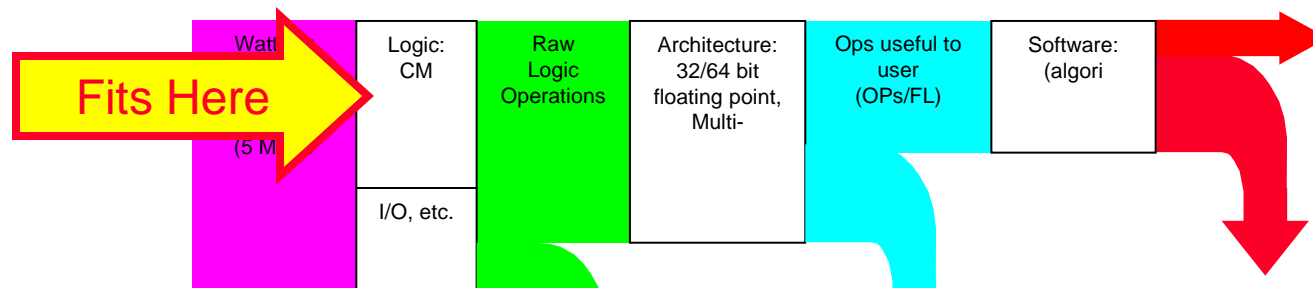# Monday Speakers

Tom Theis

- **Talk Title:** *Prospects for Computing Beyond CMOS Logic*

- **Speaker Title: Director of Physical Sciences, IBM Yorktown**

- **History: Participated in 2005 Workshop**

- **Upside Potential: Could extend Moore's Law by transition to another device concept, making it easy going for downstream participants**

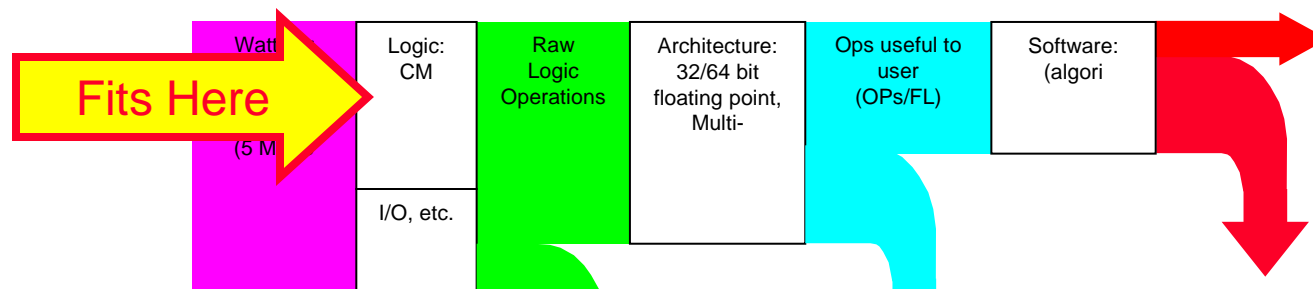| Watt	Logic: CM	Raw Logic Operations	Architecture: 32/64 bit floating point, Multi-	Ops useful to user (OPs/FL)	Software: (algori

Fits Here

(5 M

I/O, etc.

Horst Simon

- **Talk Title: *E3 Exascale Initiative***
- **Speaker Title: Acting community representative**
- **History with Workshop: Zettaflops Founder**
- **Upside Potential: E3 is an exascale initiative currently seeking funding. Both Horst and DOE/Sc are funding this workshop. If the workshop produces a useful output, E3 could see increased prospects of funding.**

George Bourianoff

- **Talk Title:** *More Moore, More than Moore, beyond CMOS and the ITRS*

- **Speaker Title: Manager of Emerging Research Technologies, Intel**

- **History: New to Workshop**

- **Upside Potential: Tracking CMOS to ultimate limits (ITRS) and discussion of other devices that may exceed CMOS capabilities**
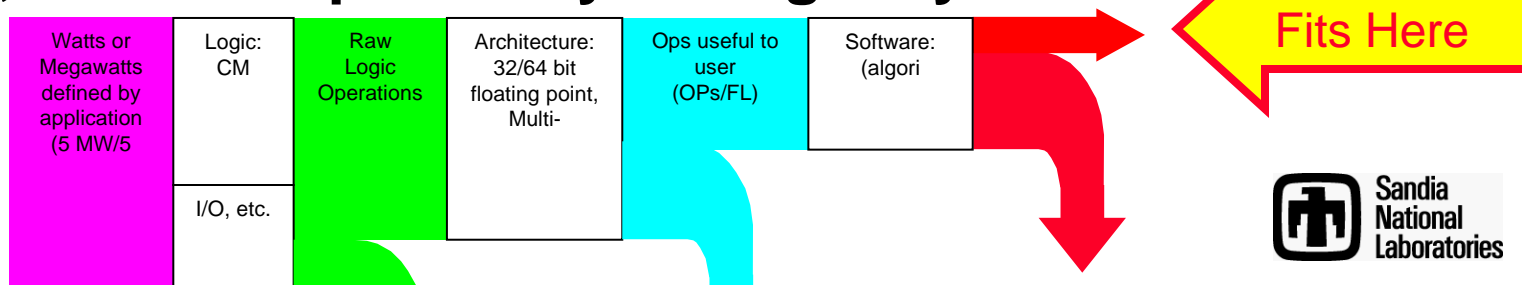
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| Watt | Logic: CM | Raw Logic Operations | Architecture: 32/64 bit floating point, Multi- | Ops useful to user (OPs/FL) | Software: (algori |

I/O, etc.

(5 M

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Phil Jones

- **Talk Title: *Climate Modeling on Future Architectures***

- **Speaker Title: Scientist, Los Alamos National Laboratory**

- **History: Presented at 2004 Workshop; David Bader presented climate modeling at 2005 workshop**

- **Upside Potential: Science validated by Nobel Prize, address "planetary emergency"**

Watts or Megawatts defined by application (5 MW/5	Logic: CM	Raw Logic Operations	Architecture: 32/64 bit floating point, Multi-	Ops useful to user (OPs/FL)	Software: (algori	
	I/O, etc.					Fits Here

Thomas Sterling

- **Talk Title:** *Operating Systems for Exascale Computing*

- **Speaker Title: Endowed Professor, LSU**

- **History: Founded workshop in 1994, continuous participant**

- **Upside Potential: Addresses a layer in the technology stack with a hard job to perform, but with upside potential. Addresses system reliability.**
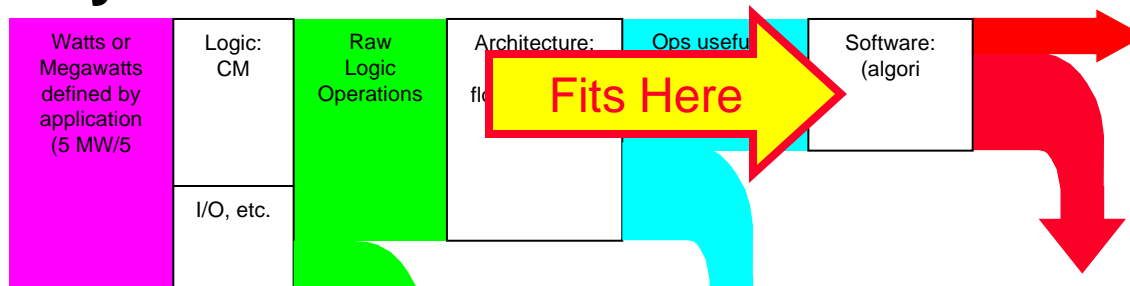
Horst Simon

- **Talk Title:** *Challenges to Reaching Exascale Computing Levels*

- **Speaker Title: Associate Laboratory Director, LBL**

- **History: In 2004, helped found Zettaflops workshop as a follow-on to the Petaflops workshops**

- **Upside Potential:**