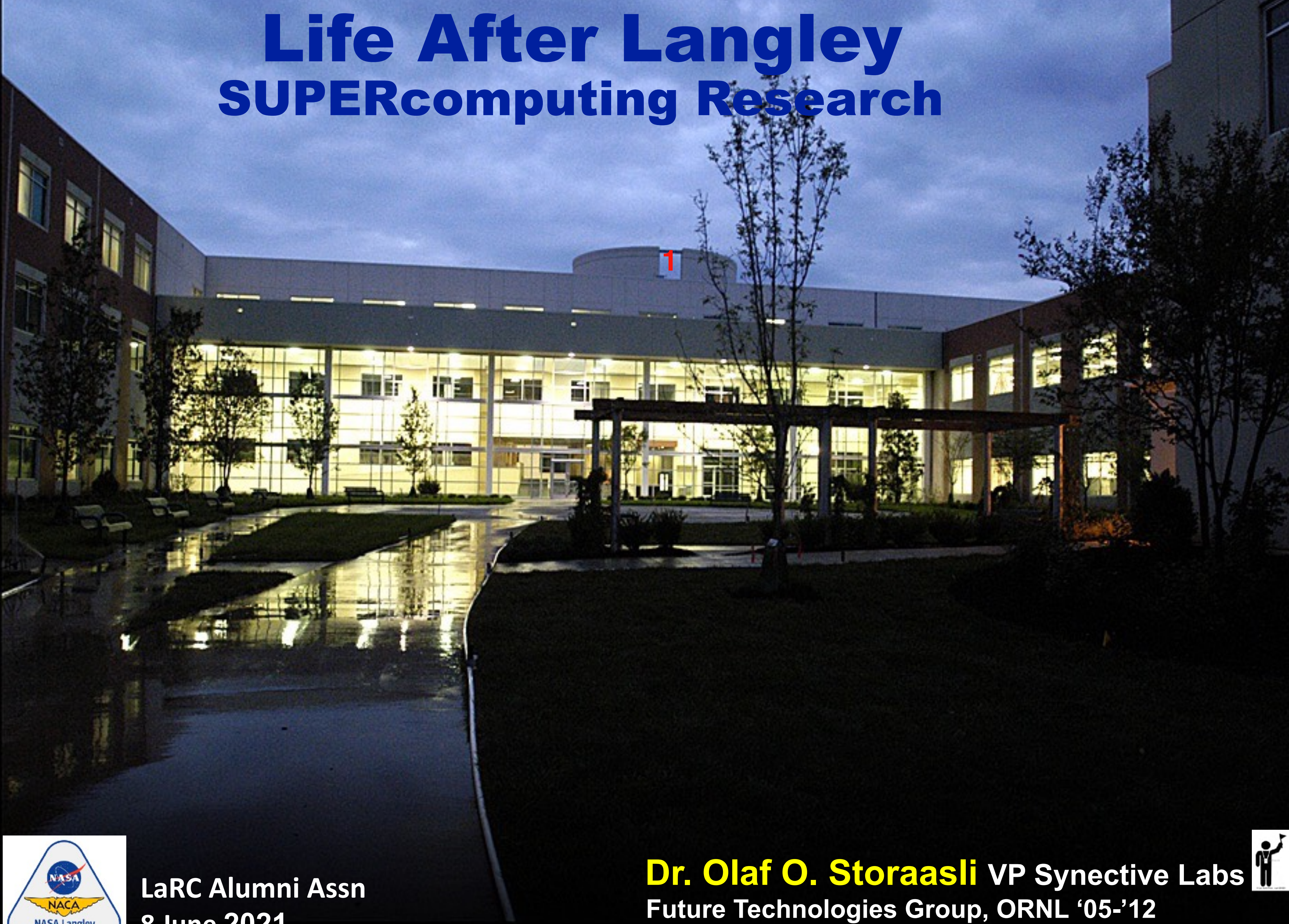
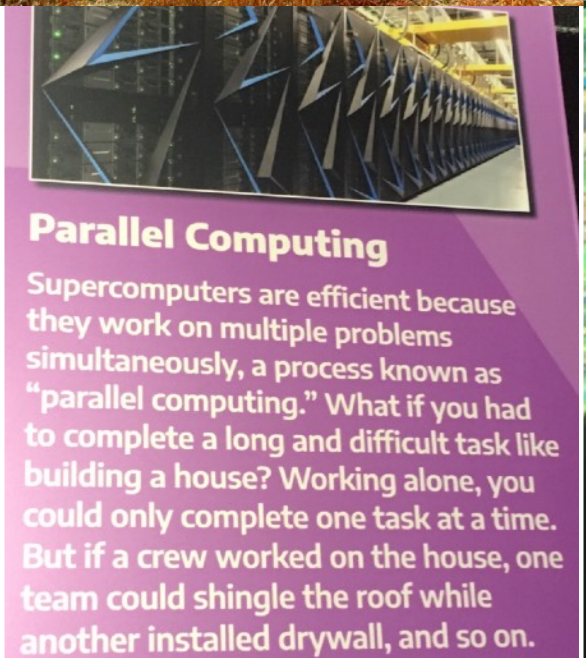
Life After Langley
SUPERcomputing Research



LaRC Alumni Assn
8 June 2021

Dr. Olaf O. Storaasli VP Synective Labs
Future Technologies Group, ORNL '05-'12
Sr. Scientist, NASA '70-'05

Prairies => VA => TN



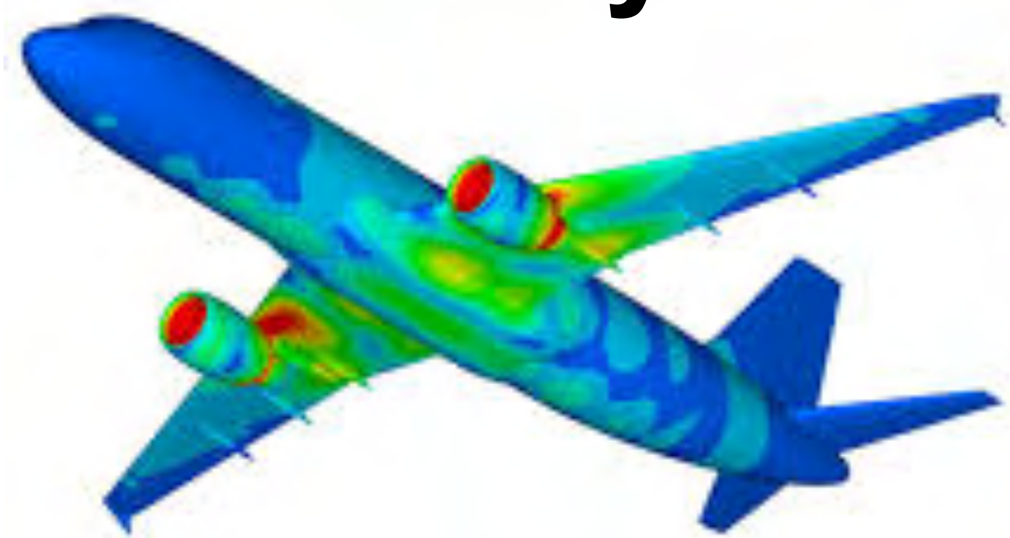
NASA Langley Research Center, Hampton VA

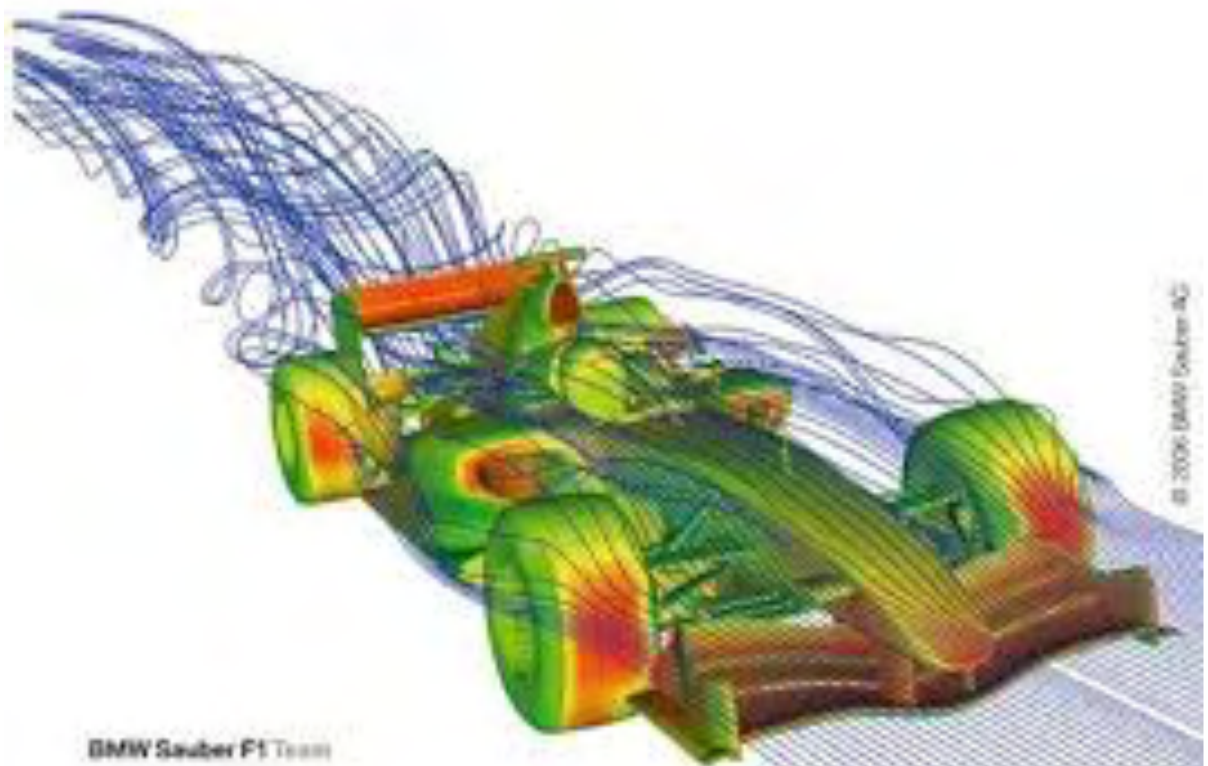
NASA Career '70-'05

FE Analysis-*Viking*-*IPAD*-CAD/CAM-*FEM*-*Shuttle*-GFA

Thompson*-GPS (SWYA)-FPGA HyperComputer-*RSC

Analysis - Top SC Use





Nastran
Dyna
Ansys
Abaqus
Star
Foam

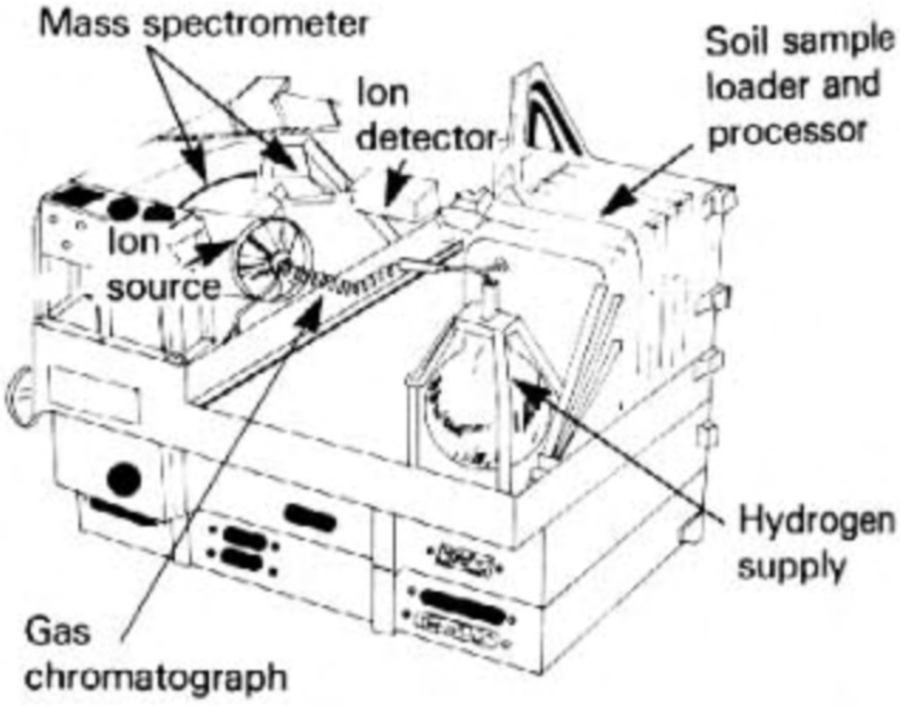
NASA Viking 1st Mars Landings

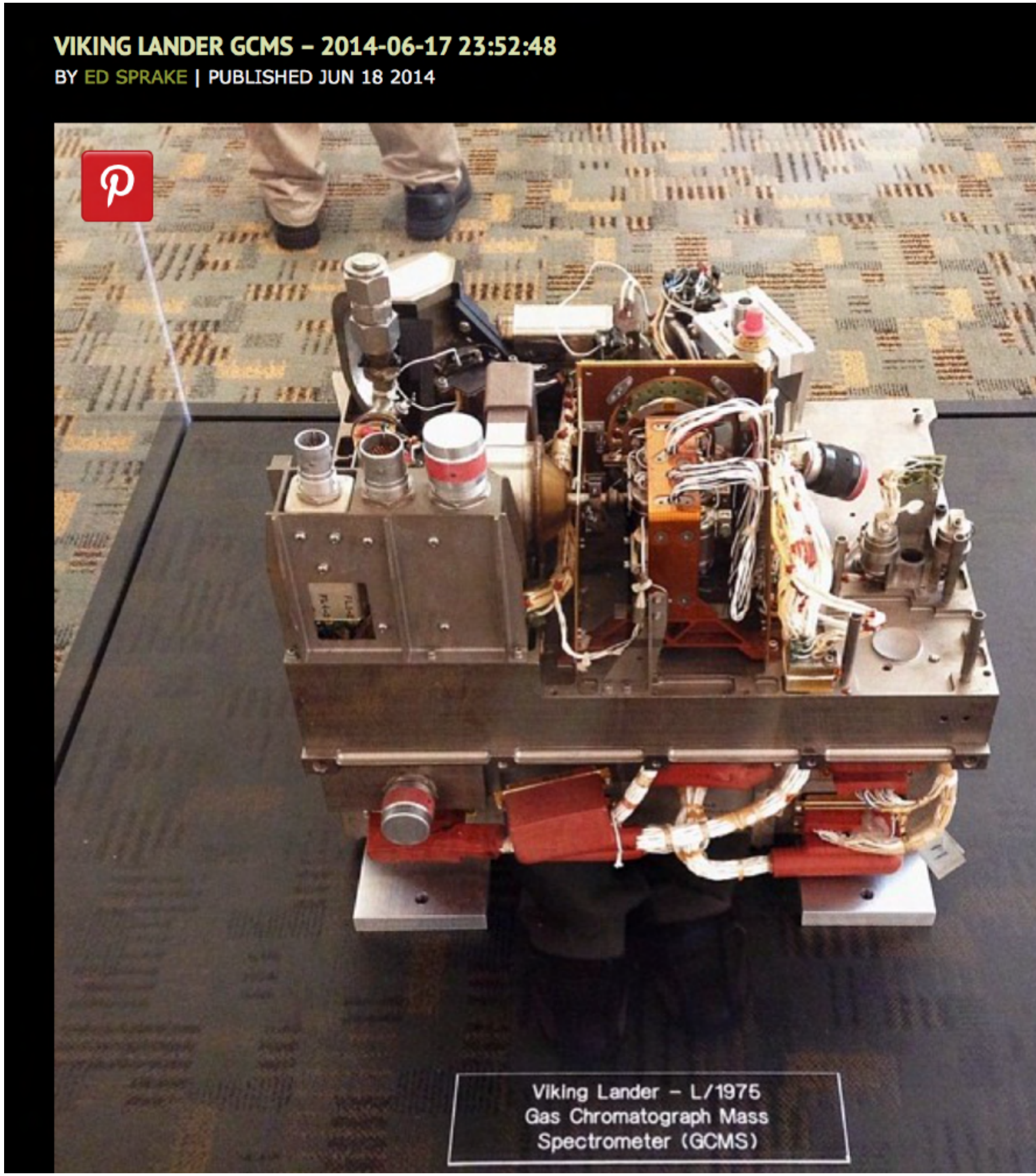
Many Langley engineers “pulled it off”

Mel Anderson - Aeroshell

Dick Snyder & Olaf - Lander

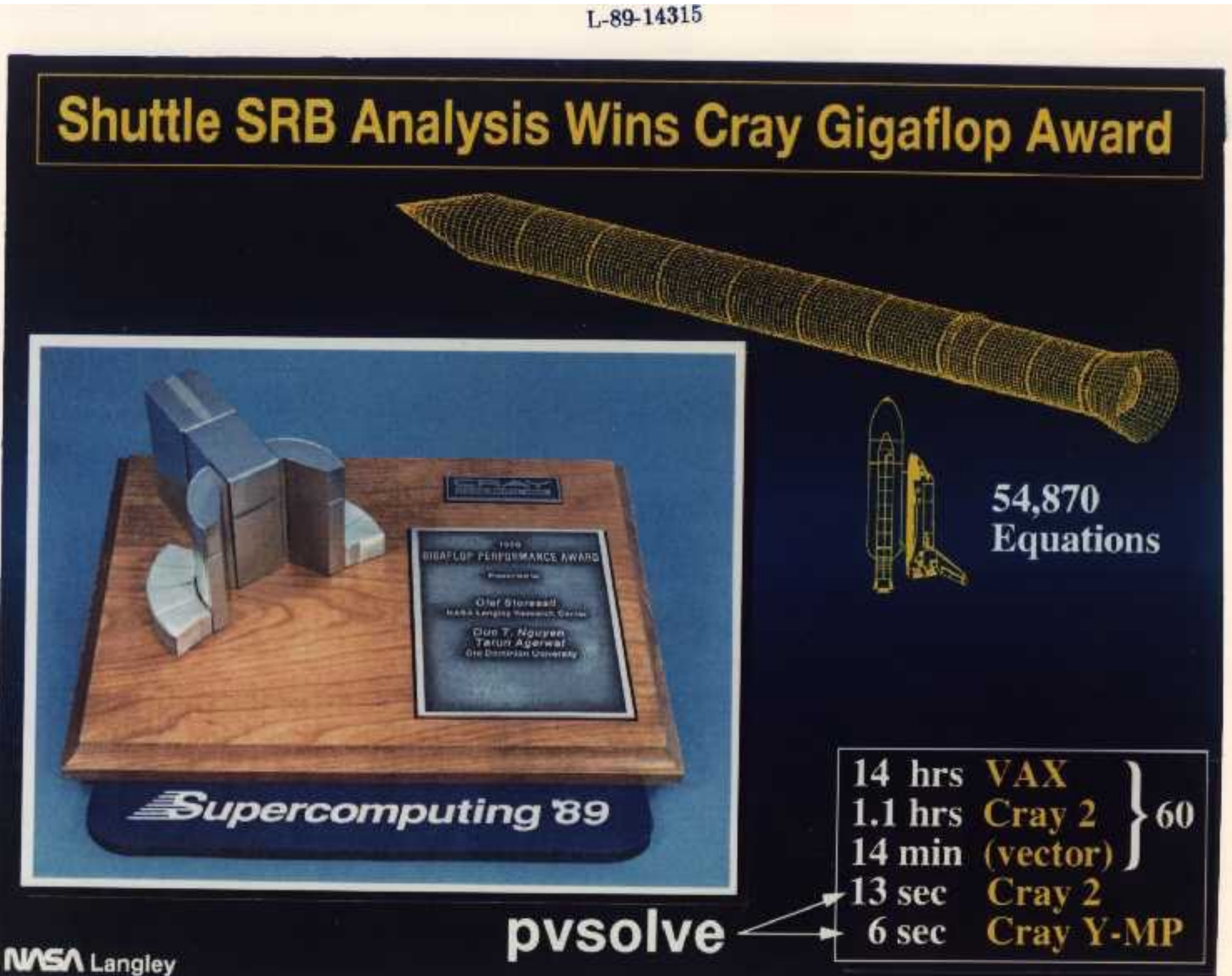
Viking Lander GCMS "box"
LaRC Tiger Team redesign, build & test





Space Shuttle (pre/post Challenger)

- Wing/tail structural analysis
- Solid Rocket Booster Redesign



US Supercomputer Lead

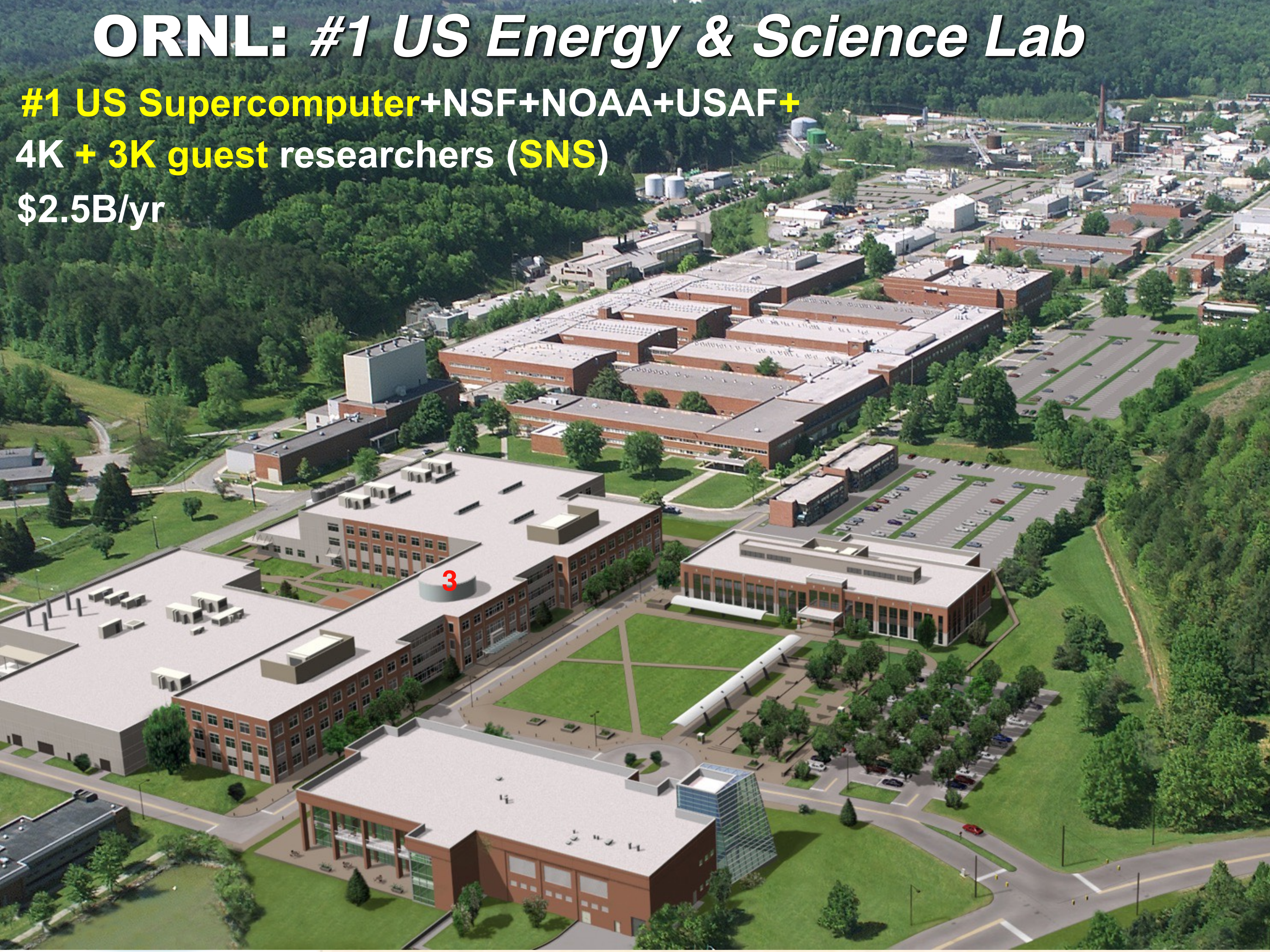
How? MC, GPU, FPGA, Cell?

Manhattan Project X10 -> ORNL

[Gas Centrifuge, Y12, S50, K25]

X10: 1st Pilot Pu Reactor => PNL

Y12 *Ernest Lawrence + uncle built Calutrons to enrich U*


ORNL: #1 US Energy & Science Lab
#1 US Supercomputer+NSF+NOAA+USAF+
4K + 3K guest researchers (SNS)
$2.5B/yr
3

Change LaRC => DOE

GOGO vs. GOCO (JPL)

Security Physical & Cyber

TOP SECRET

EXPORT CONTROLS

INTERNATIONAL TRAFFIC IN ARMS ITAR REGULATIONS COMPLIANT

Rewards Freedom, Pubs/Talks/Travel(Intl)

Research respect: ORNL-US-SCworld

+50%$, 6wk vac, 3Xretire, ClubORNL

Colleagues* PhDs, Natl/Intl, Teams

Cyber leads, young, Seminars

*LANL, LLNL, LBL, ANL, UT, DARPA, NSA, SC

Future Technologies Group

Oak Ridge National Laboratory

DOE Security

Redo NASA Conf/Secret/TS => L/Q/SCI*Fs
Bldg control, TS+SCI monthly training

Why? US Nuke (U) Depository+Codes
Store/Produce/Control/Lend U to DOD+
TS ORNL Dir+4 SCI-trained 3hrs for OS talk

TS Cyber Security: air gap @Secret Site

Control code, talk, notes, phones, cameras, USB
How to write TS code?

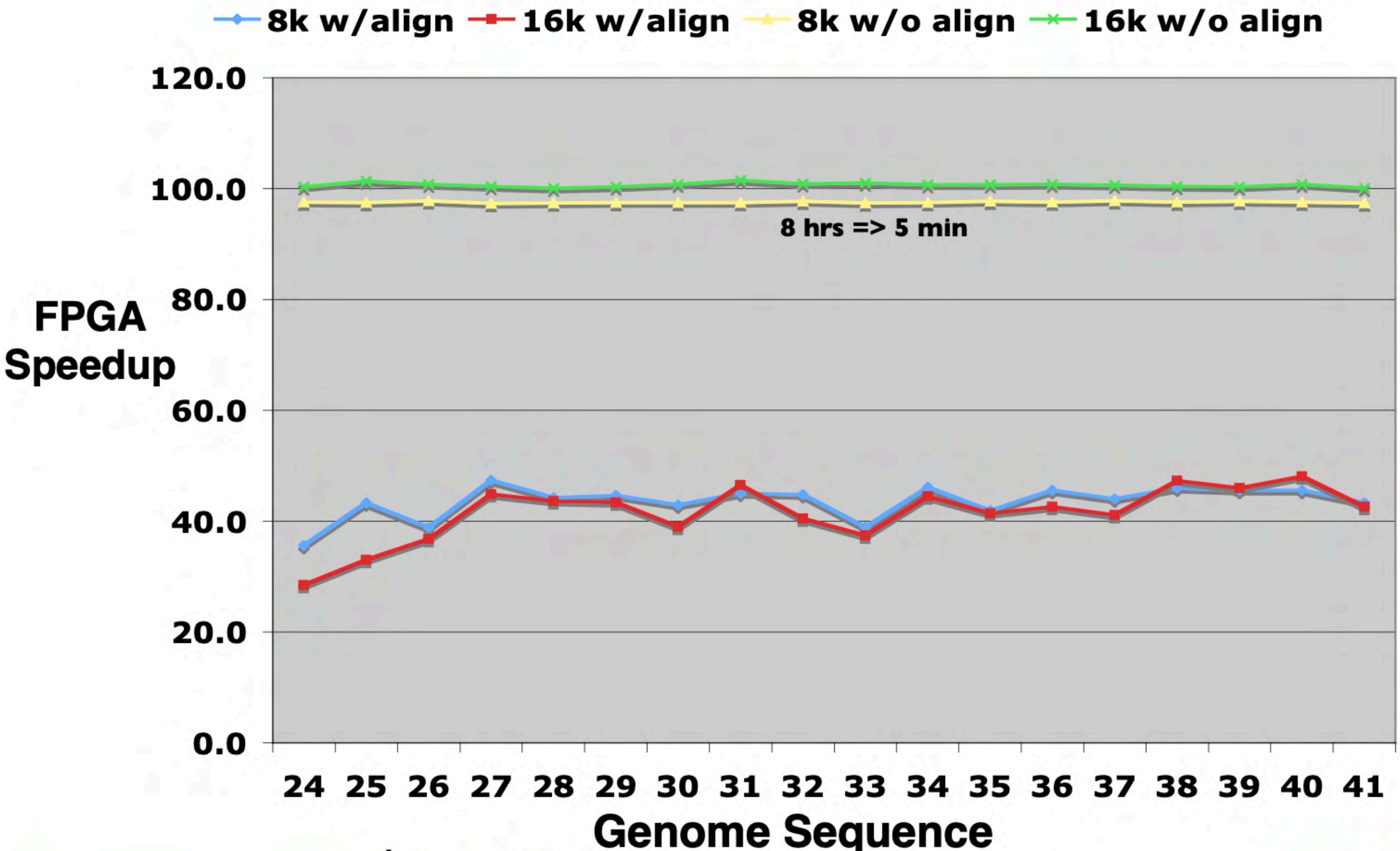
*Sensitive Compartmented Information

Future Technologies Group

Oak Ridge National Laboratory

100x* DNA Sequence Speedup

***Bacillus anthracis* Human DNA comparison**



*Virtex-4 FPGA vs 2.2 GHz Opteron on Cray XD1

ORNL Fast DNA sequencing

12.5 years on one 2.2 GHz Opteron

6 weeks on 150 Opterons

1 day on 150 FPGAs*

***7,350X Speedup* over one Opteron**

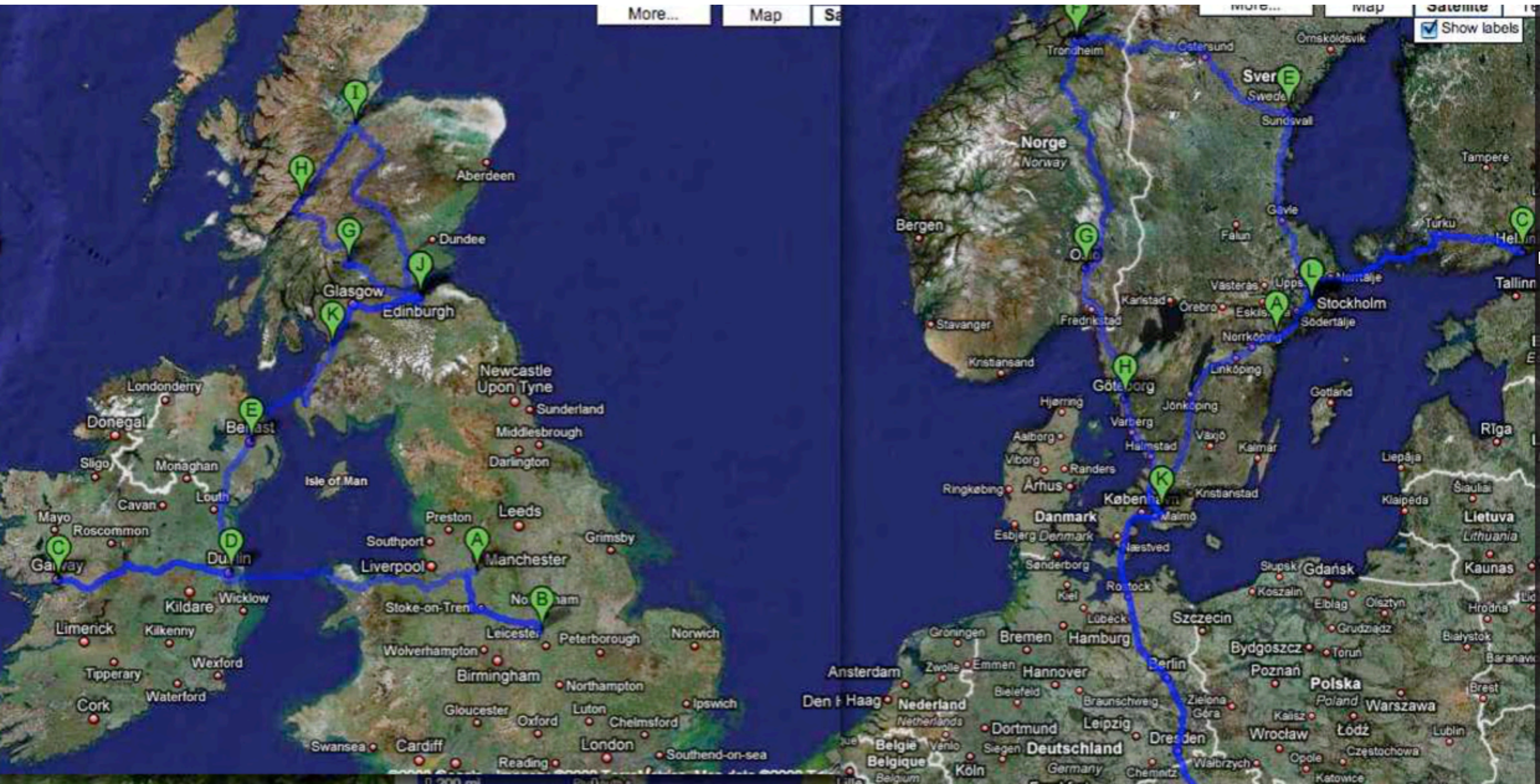
also tested *64 FPGA Maxwell*
@Edinburgh University

*Thanks to NRL for use of 150 FPGA Cray XD1

’08 Invited Talks: Mar-Jun, Apr U PostDoc*
Queens U (Belfast), Edinburgh*, Helsinki, Trondheim, Oslo, Göteborg, Lund, Budapest

’05-08:UK, ‘05 Brazil, ’13 NO SE FI ES, ’15: NL Paris

’16 BE NO SE ES GEx2 FI Russia ’17 UK: Queens+Imperial



Cray Users Group (Helsinki)

Meghívó

Nagyságrendekkel hatékonyabb számítási módszerek a gyógyszerkutatásban című konferenciára

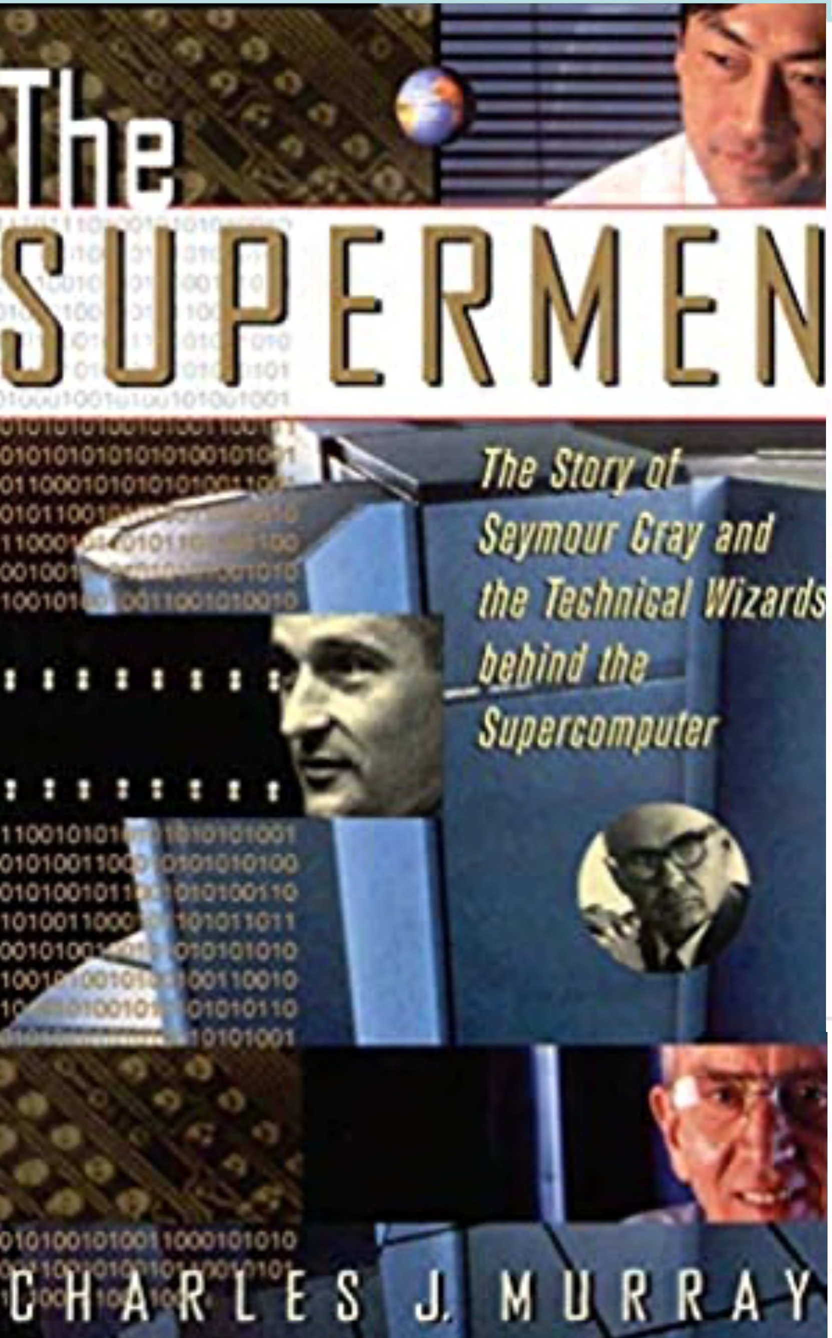
Programterv

9:00 – 9:30 Regisztráció
9:30 – 9:40 Köszöntő (Mészáros Csaba, evopro Kft. ügyvezetője)
9:40 – 10:00 A projekt története (Bérces Attila, Chemistry Logic Kft. ügyveze
10:00 – 10:10 Újrakonfigurálható számítástechnika felhasználóknak (Fehér Béla, BME MIT)
10:10 – 10:50 Accelerating Genome Sequencing 100-1000X with FPGA
(Prof. Olaf Storaasli, Oak Ridge National National Laboratory kutatója)

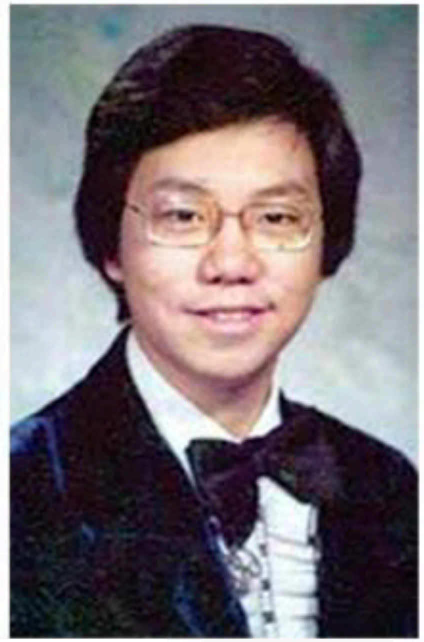
“To Hell (Norway) & Back”

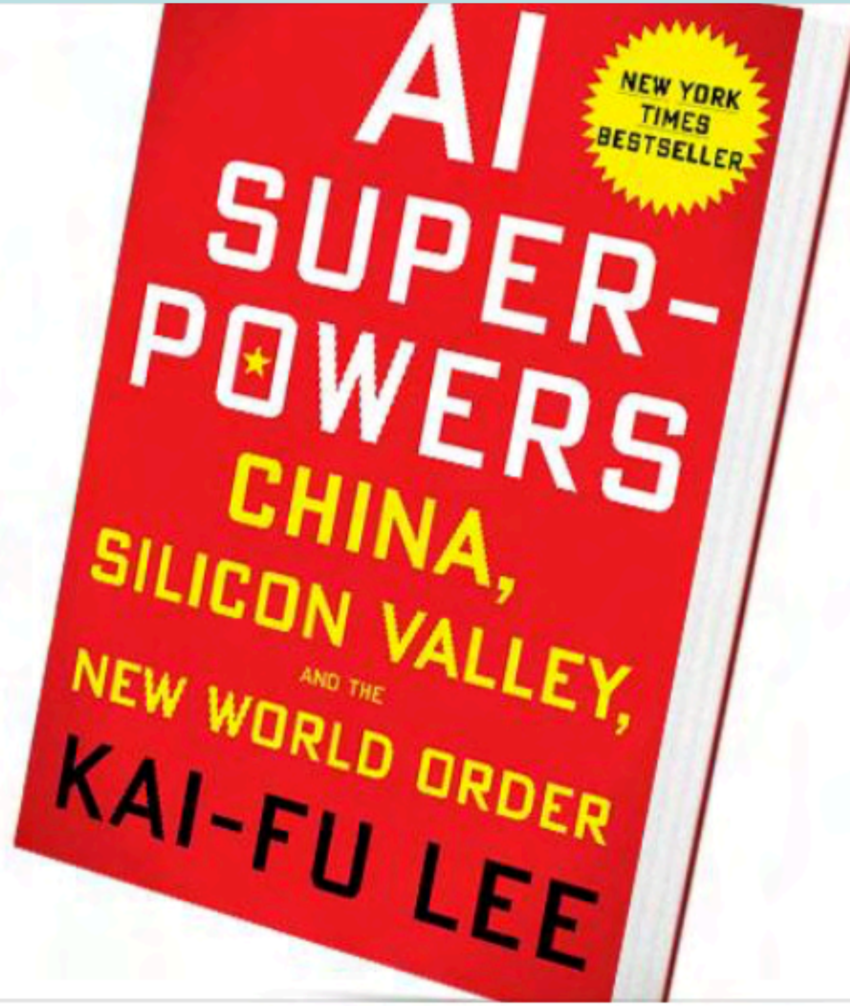
Motivation

Past



Future





Microsoft

Google

This is the most important tech contest since the space race, and America is losing

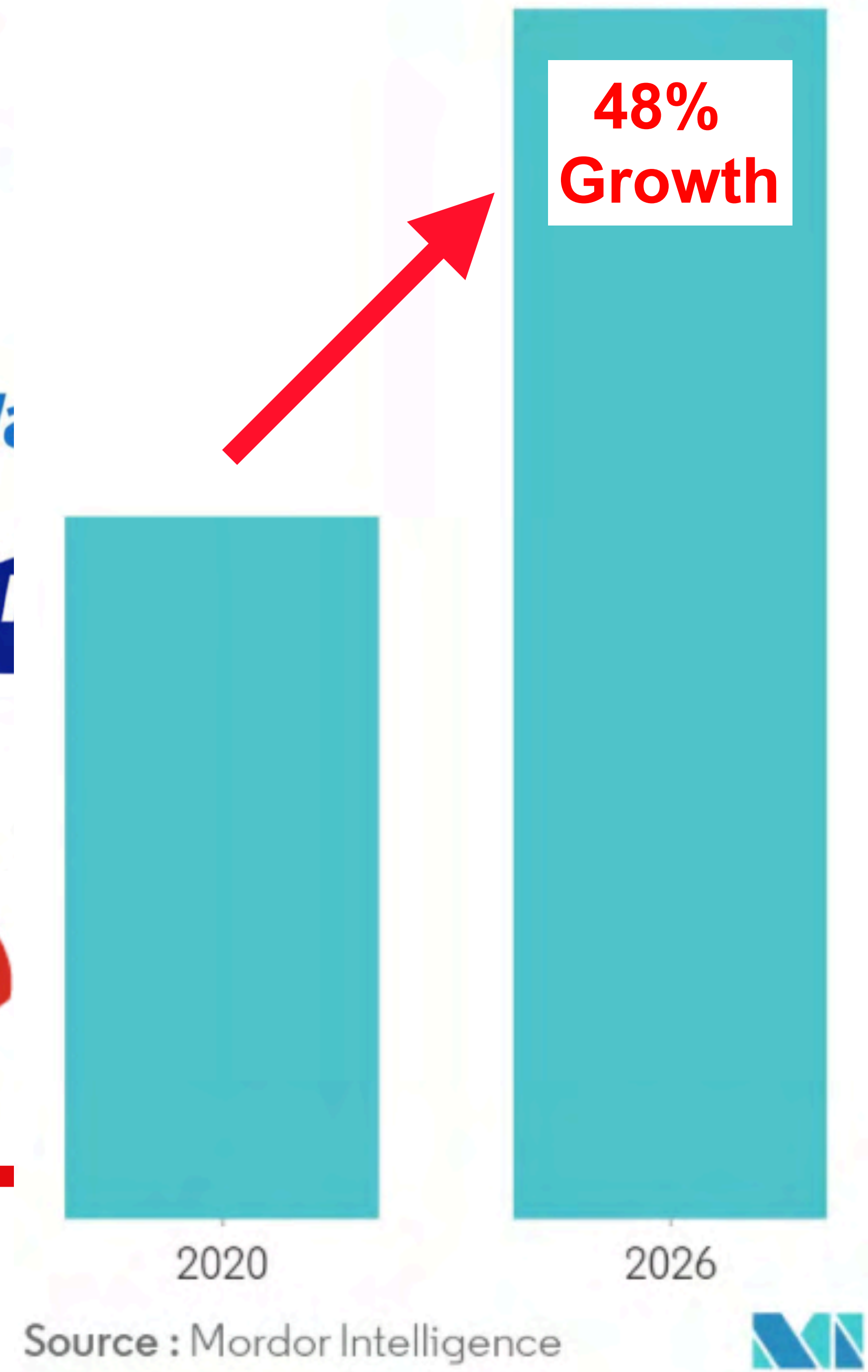
WP Max Nikias

QC

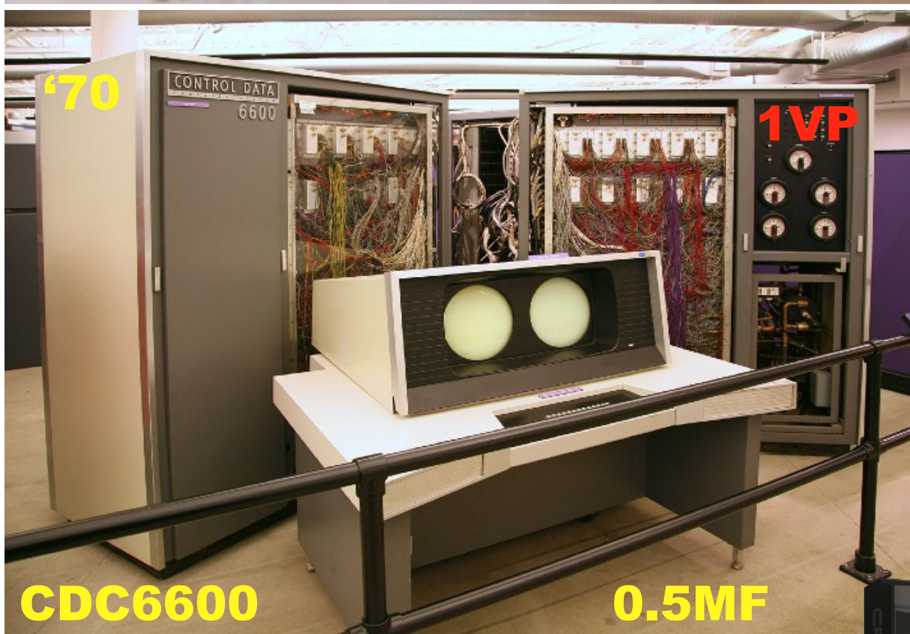
Technical Computer Market

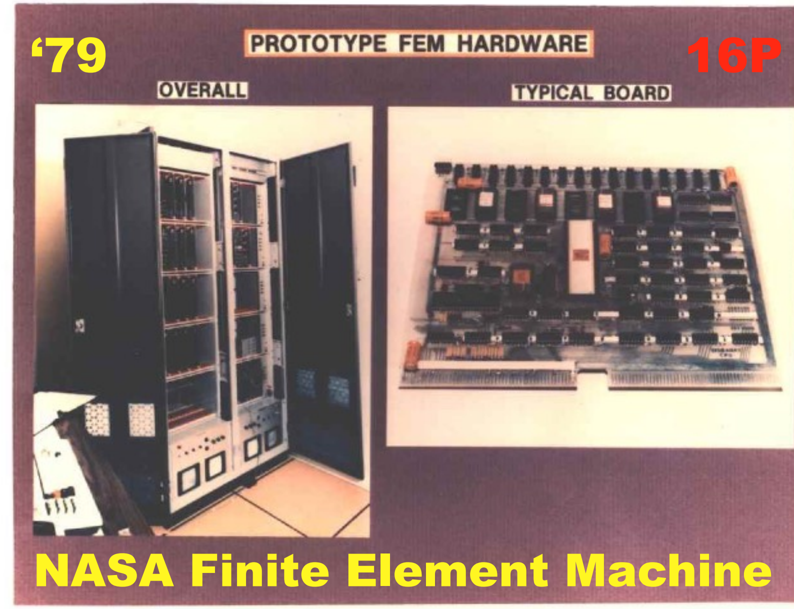
$10B ('13) => $15B ('18) **SC: $4B => $5.7B**

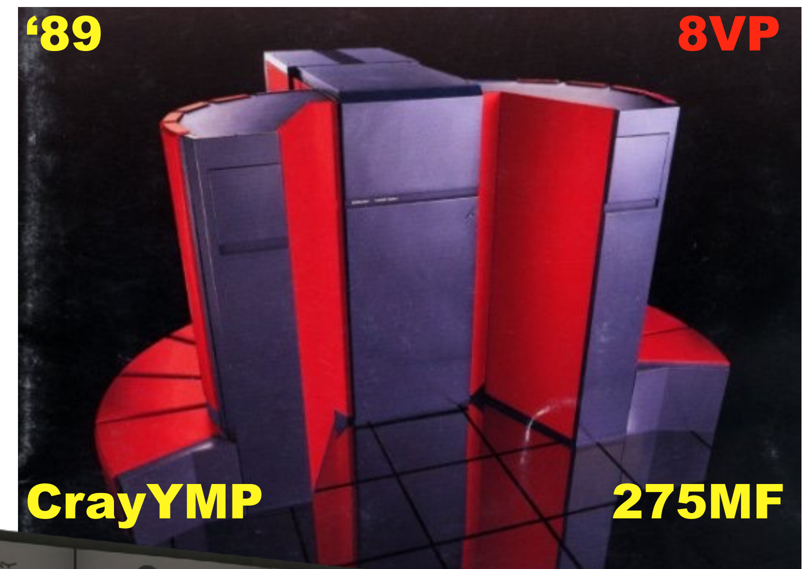
1960s



Past 57-yr Speedup







Now

Frontier: '21/'64 = 1.5EF/1.5KF

EF=10^18 / KF=10^3

1,000,000,000,000,000 X faster

World's 500 Fastest Computers

TOP 500 The List. top500.org June/ISC, Nov/SC

Linpack Benchmark: *Ax=b* **Jack Dongarra**

Try! *My iPhoneXr ~* ***21GF***

Craig Hunter ***MacPro28 ~ 1.5TF***

SC18
Dallas, TX
November 11-16, 2018

SC17
Denver, CO
November 12-17, 2017
Conference Proceedings

SC16
Salt Lake City, UT
November 13-18, 2016
Conference Proceedings

SC15
Austin, TX
November 15-20, 2015
Conference Proceedings

SC14
New Orleans, LA
November 16-21, 2014
Conference Proceedings

SC13
Denver, CO
November 18-21, 2013
Conference Proceedings

SC12
Salt Lake City, UT
November 10-16, 2012
Conference Proceedings

SC11
Seattle, WA
November 12-18, 2011
Conference Proceedings

SC10
New Orleans, LA
November 13-19, 2010
Conference Proceedings

SC09
Portland, OR
November 14-20, 2009
Conference Proceedings

SC08
Austin, TX
November 2008
Conference Proceedings

SC07
Reno, NV
November 10-16, 2007
Conference Proceedings

Linpack Benchmark

Linpack

5 Ratings

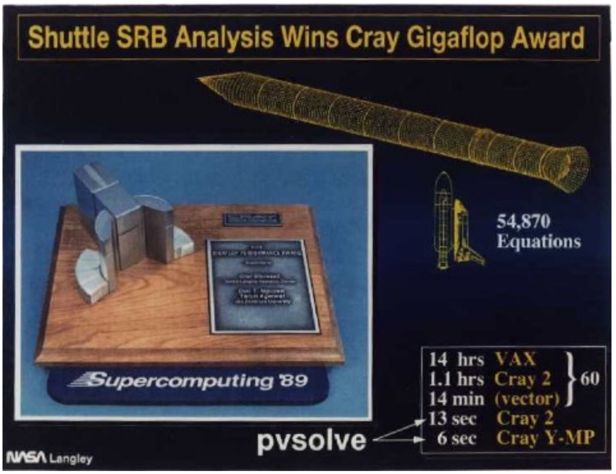
FREE

Linpack Benchmark

The LINPACK Benchmarks are a measure of a system's floating point computing power. They measure how fast a computer solves a dense N by

HPC Speedup: 1000X per Decade

Evolution of the fastest sustained performance in real simulations



~1 Exaflop/s
~10^7 processing units
(ORNL?)

1.35 Petaflop/s
Cray XT5
1.5 10^5 processor cores
(Shultness - ORNL)

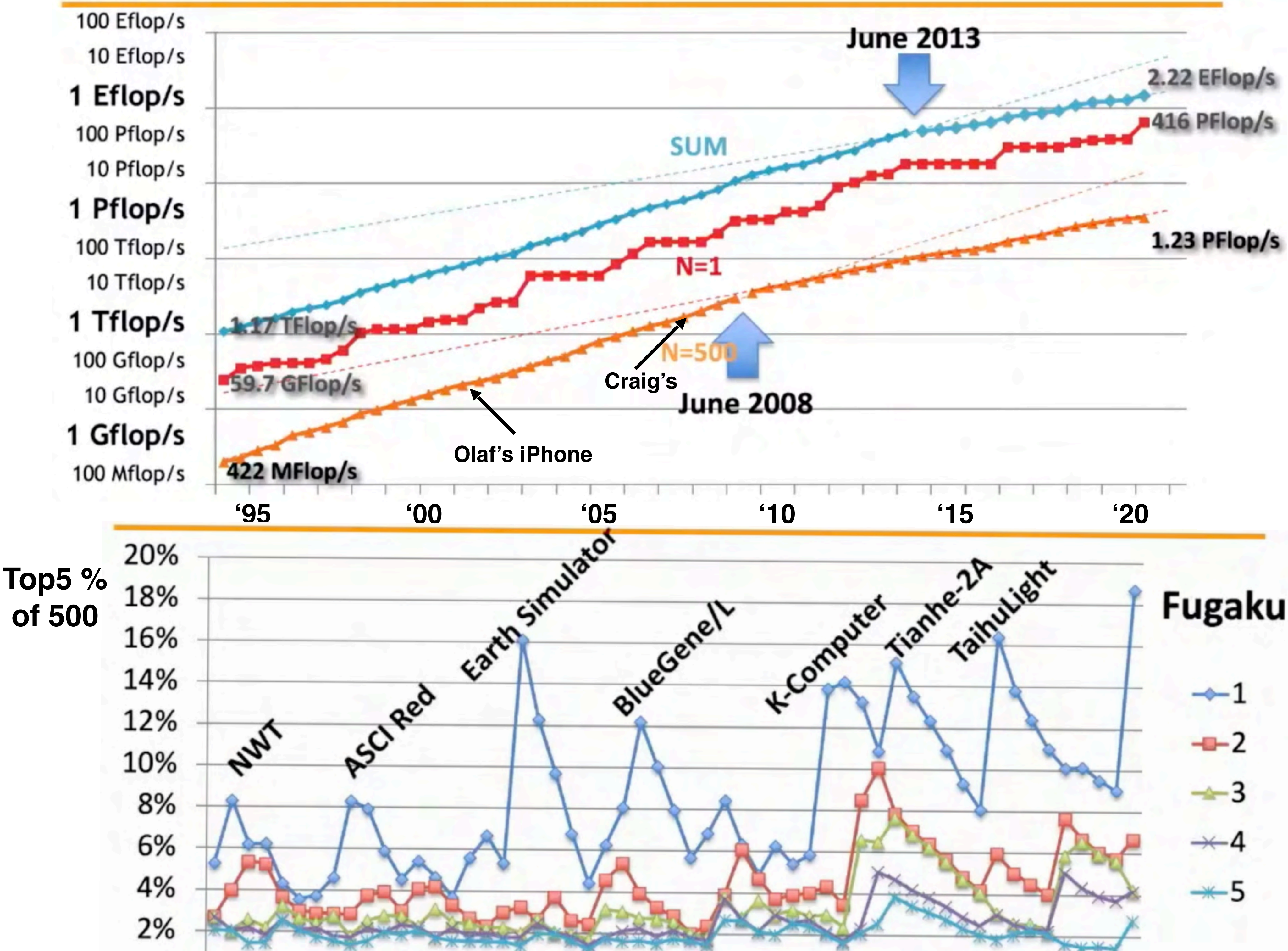
1.02 Teraflop/s
Cray T_{3D}
1.5 10^3 processors
(ORNL)

1.5 Gigaflop/s
Cray YMP
0.8 10^1 processors
(Storaasli - NASA)

1989 | 1998 | 2008 | 2021

10^12 Mflops = 10^9 Gigaflops = 10^6 Teraflops = 1,000 Petaflops = 1 Exaflop

Supercomputer Speedup

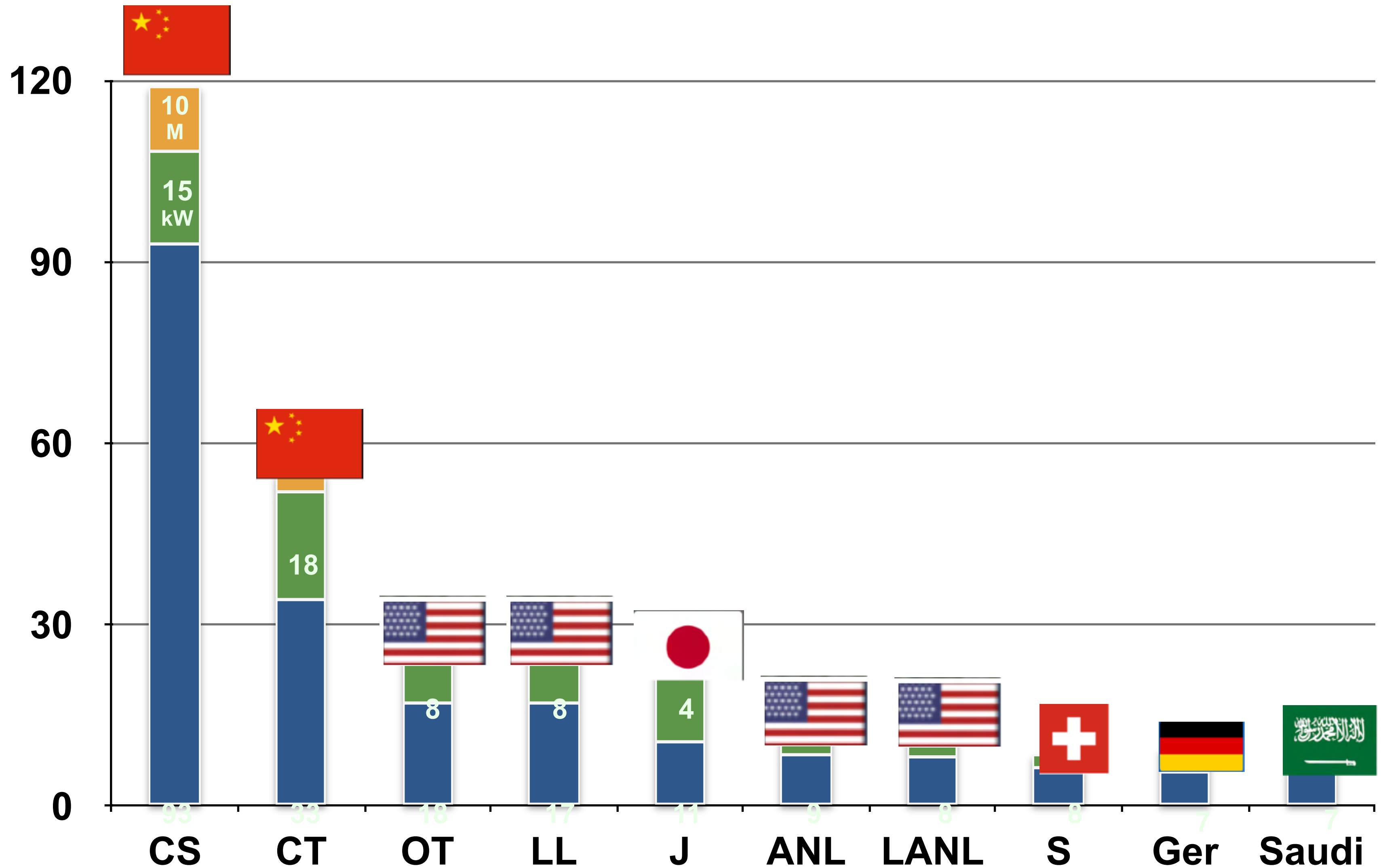


November 2012: The TOP10

Rank	Site	Computer	Country	Cores	Rmax [Pflops]	% of Peak	Power [MW]	MFlops /Watt
1	DOE / OS Oak Ridge Nat Lab	Titan, Cray XK7 (16C) + Nvidia Kepler GPU (14c) + custom	USA	560,640	17.6	66	8.3	2120
2	DOE / NNSA L Livermore Nat Lab	Sequoia, BlueGene/Q (16c) + custom	USA	1,572,864	16.3	81	7.9	2063
3	RIKEN Advanced Inst for Comp Sci	K computer Fujitsu SPARC64 VIIIfx (8c) + custom	Japan	705,024	10.5	93	12.7	827
4	DOE / OS Argonne Nat Lab	Mira, BlueGene/Q (16c) + custom	USA	786,432	8.16	81	3.95	2066
5	Forschungszentrum Juelich	JuQUEEN, BlueGene/Q (16c) + custom	Germany	393,216	4.14	82	1.97	2102
6	Leibniz Rechenzentrum	SuperMUC, Intel (8c) + IB	Germany	147,456	2.90	90*	3.42	848
7	Texas Advanced Computing Center	Stampede, Dell Intel (8) + Intel Xeon Phi (61) + IB	USA	204,900	2.66	67	3.3	806
8	Nat. SuperComputer Center in Tianjin	Tianhe-1A, NUDT Intel (6c) + Nvidia Fermi GPU (14c) + custom	China	186,368	2.57	55	4.04	636
9	CINECA	Fermi, BlueGene/Q (16c) + custom	Italy	163,840	1.73	82	.822	2105
10	IBM	DARPA Trial System, Power7 (8C) + custom	USA	63,360	1.51	78	.358	422
500	Slovak Academy Sci	IBM Power 7	Slovak Rep	3,074	.077	81		

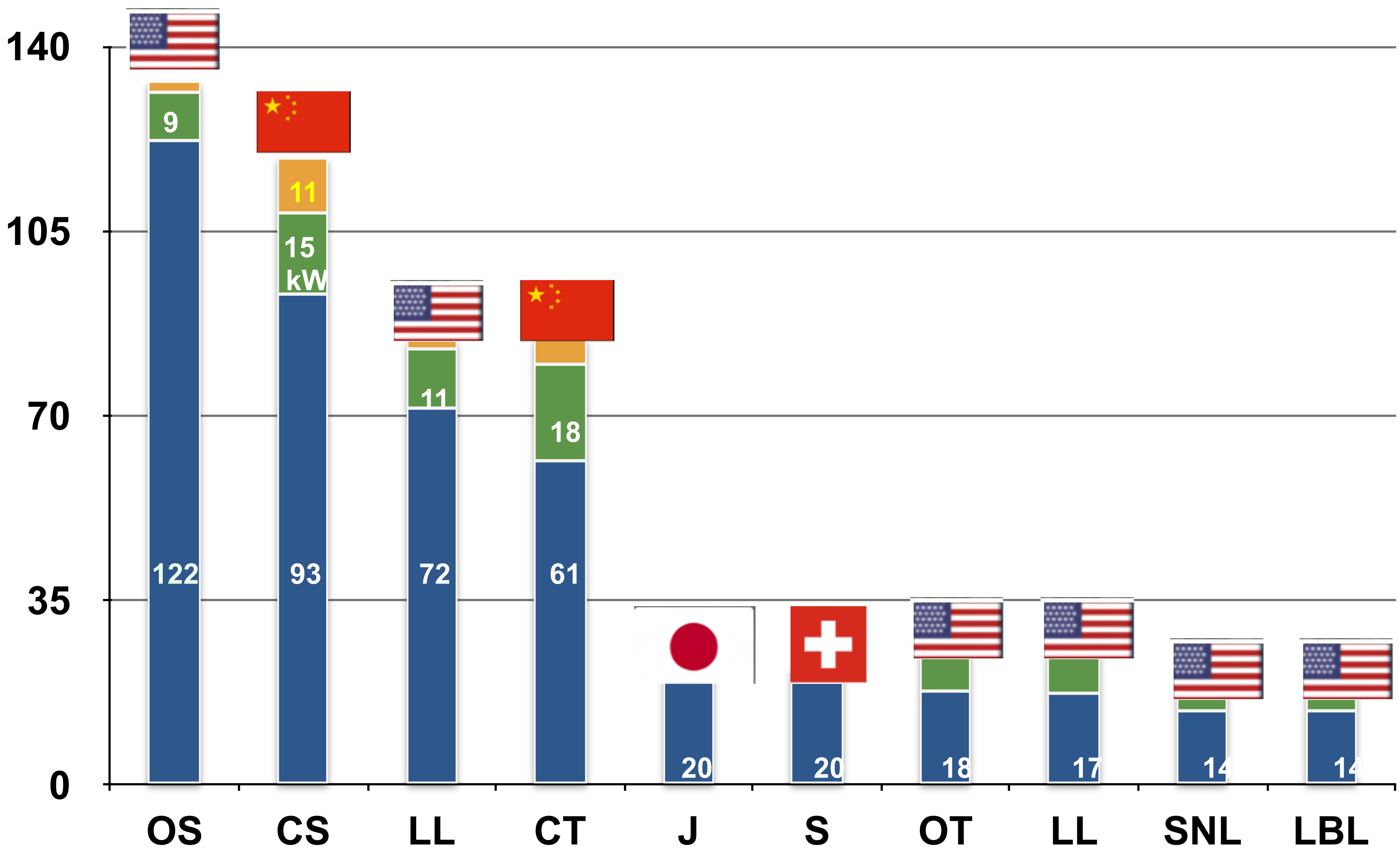
Top10 Supercomputers June 2016

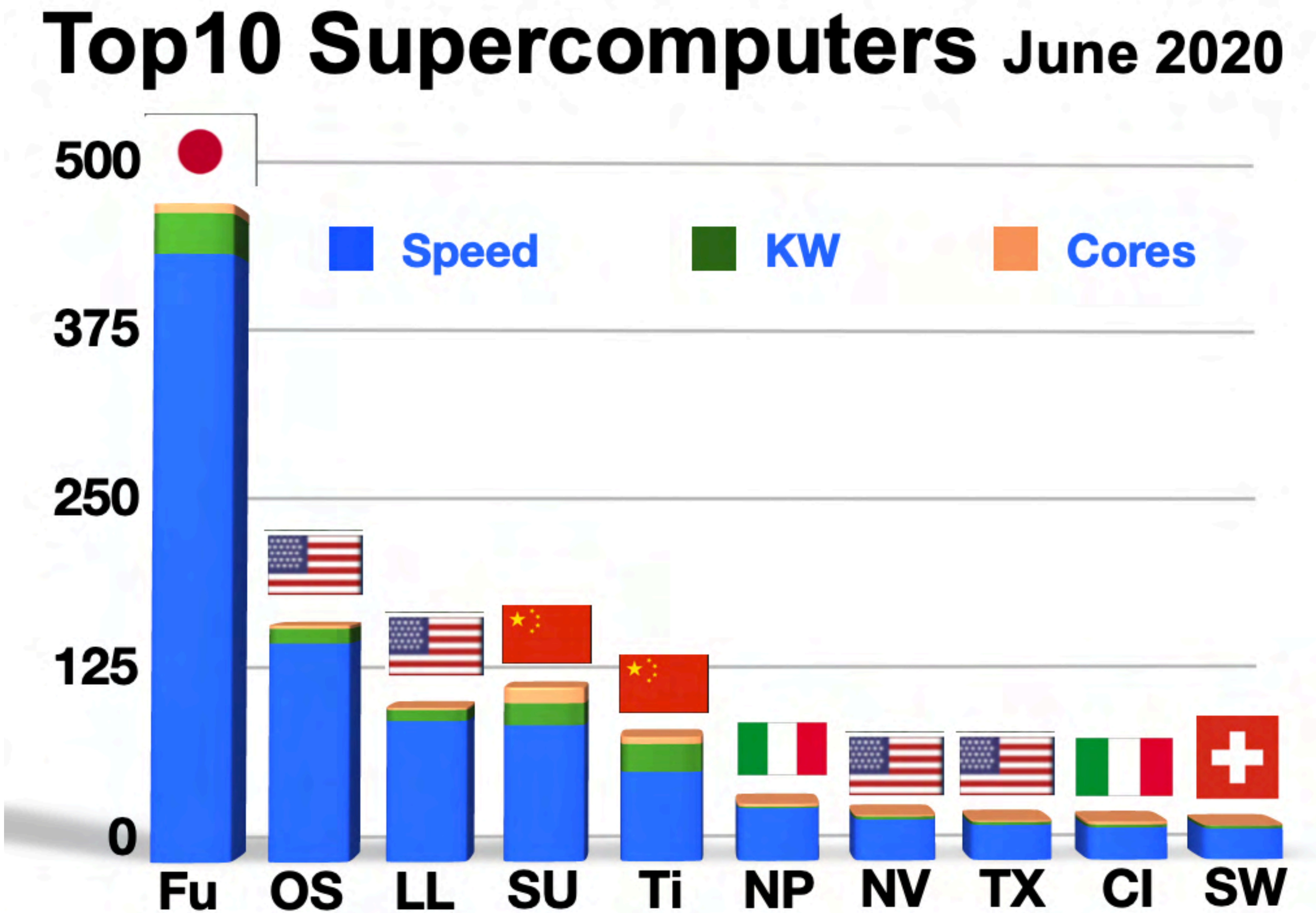
Speed-TF, Power-kW, Cores-M



Top10 Supercomputers June 2018

Speed-TF, Power-kW, Cores-M




Top10 Supercomputers June 2020
500
375
250
125
0
Speed
KW
Cores
Fu
OS
LL
SU
Ti
NP
NV
TX
CI
SW

Top10 Supercomputers June 2020

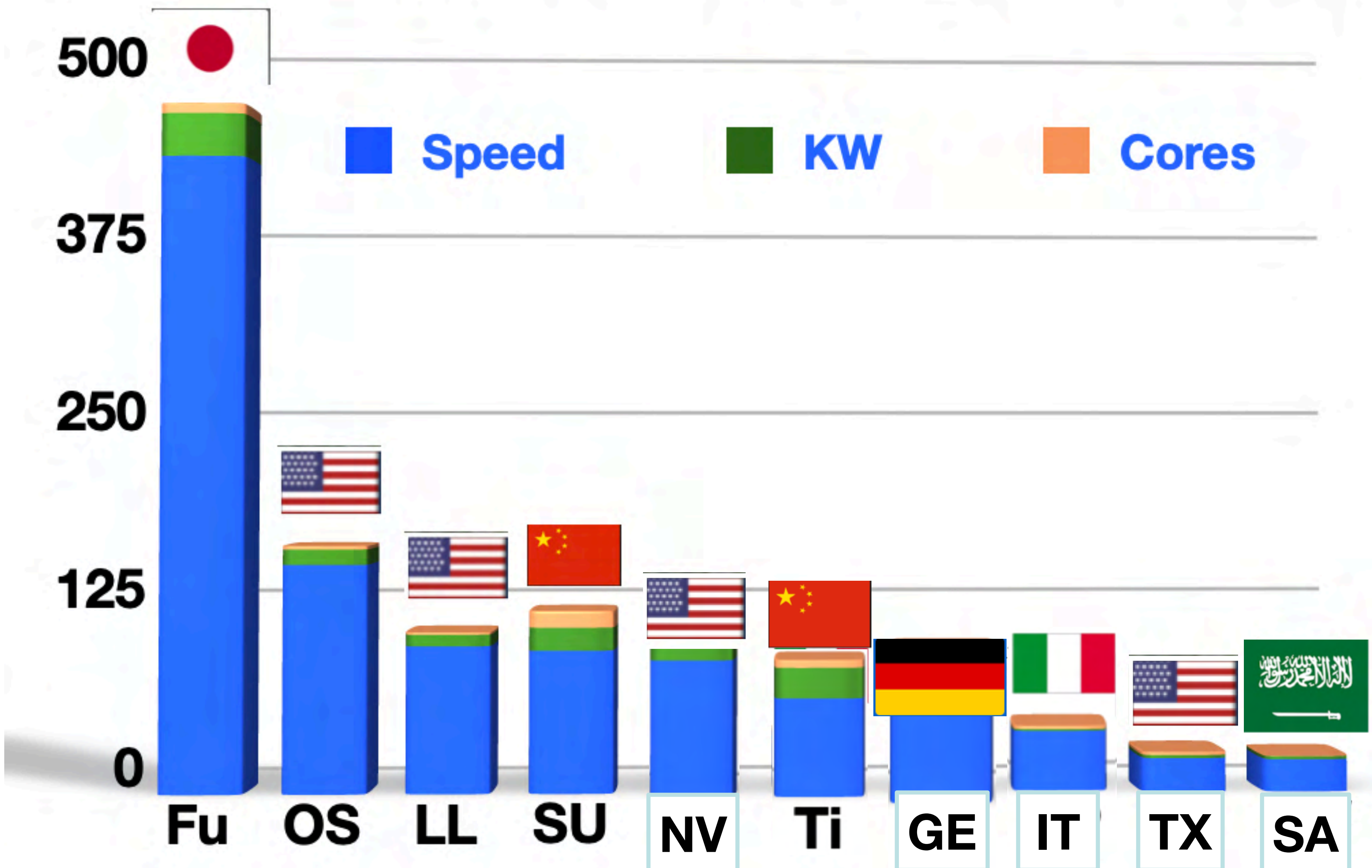
#	Site	Manufacturer	Computer	Country	Cores	Rmax [Pflops]	Power [MW]
1	RIKEN Center for Computational Science	Fujitsu	Fugaku Supercomputer Fugaku, A64FX 48C 2.2GHz, Tofu interconnect D	Japan	7,299,072	415.5	28.3
2	Oak Ridge National Laboratory	IBM	Summit IBM Power System, P9 22C 3.07GHz, Mellanox EDR, NVIDIA GV100	USA	2,414,592	148.6	10.1
3	Lawrence Livermore National Laboratory	IBM	Sierra IBM Power System, P9 22C 3.1GHz, Mellanox EDR, NVIDIA GV100	USA	1,572,480	94.6	7.4
4	National Supercomputing Center in Wuxi	NRCPC	Sunway TaihuLight NRCPC Sunway SW26010, 260C 1.45GHz	China	10,649,600	93.0	15.4
5	National University of Defense Technology	NUDT	Tianhe-2A ANUDT TH-IVB-FEP, Xeon 12C 2.2GHz, Matrix-2000	China	4,981,760	61.4	18.5
6	Eni S.p.A	Dell EMC	HPC5 PowerEdge C4140, Xeon 24C 2.1GHz, NVIDIA T. V100, Mellanox HDR	Italy	669,760	35.5	2.25
7	NVIDIA Corporation	NVIDIA	Selene DGX A100 SuperPOD, AMD 64C 2.25GHz, NVIDIA A100, Mellanox HDR	USA	277,760	27.6	1.34
8	Texas Advanced Computing Center / Univ. of Texas	Dell	Frontera Dell C6420, Xeon Platinum 8280 28C 2.7GHz, Mellanox HDR	USA	448,448	23.5	
9	CINECA	IBM	Marconi-100 IBM Power System AC922, P9 16C 3GHz, Nvidia Volta V100, Mellanox EDR	Italy	347,776	21.6	1.98
10	Swiss National Supercomputing Centre (CSCS)	Cray	Piz Daint Cray XC50, Xeon E5 12C 2.6GHz, NVIDIA Tesla P100, Aries	Switzerland	387,872	21.2	2.38

new to Top10

#1 EF for HPL-AI (less precision)

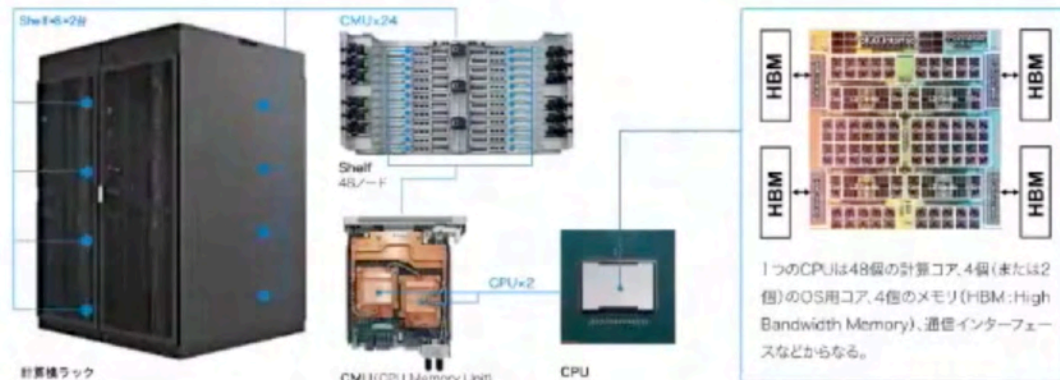
15GF/W 1-3
6-3GF/W 4-5

Top10 Supercomputers Nov 2020



#1 Supercomputer Fugaku = 537 PF

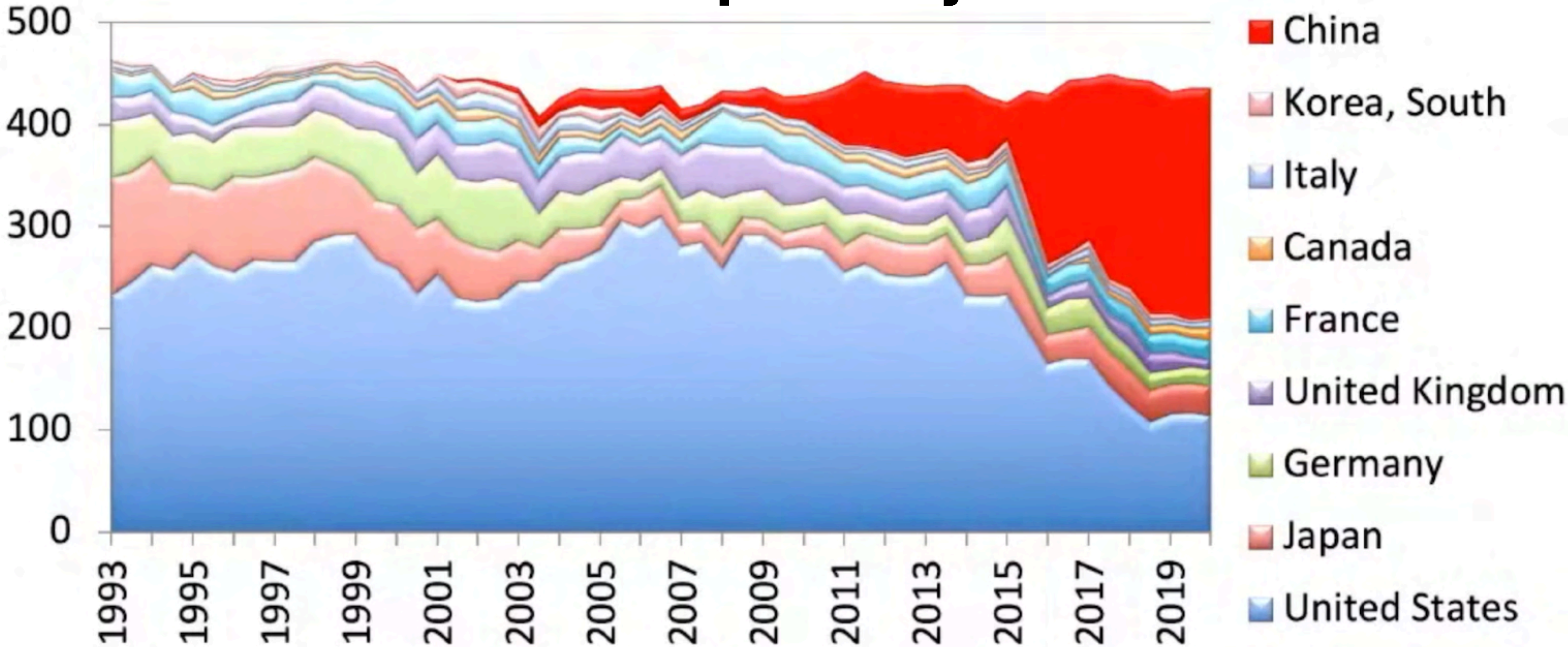
- **Total # Nodes: 158,976 nodes**
  - 384 nodes/rack x 396 (full) racks = 152,064 nodes
  - 192 nodes/rack x 36 (half) racks = 6,912 nodes
- **Theoretical Peak Compute Performances**
  - Boost Mode (CPU Frequency 2.2GHz)
    - 64 bit Double Precision FP: 537 Petaflops
    - 32 bit Single Precision FP: 1.07 Exaflops
    - 16 bit Half Precision FP (AI training): 2.15 Exaflops
    - 8 bit Integer (AI Inference): 4.30 Exaops
- **Theoretical Peak Memory Bandwidth: 163 Petabytes/s**

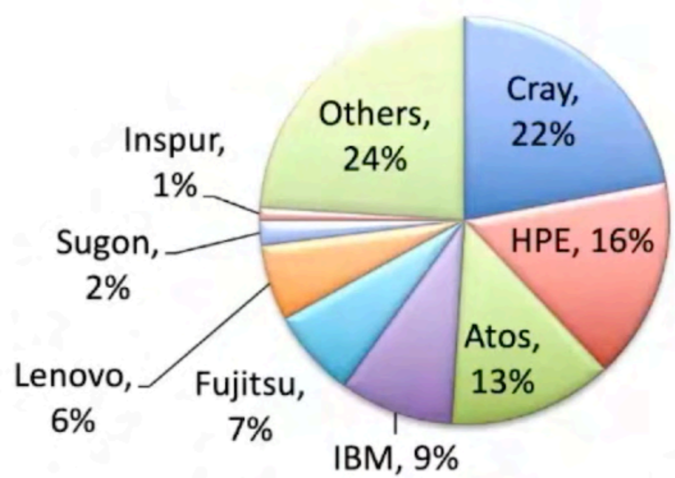


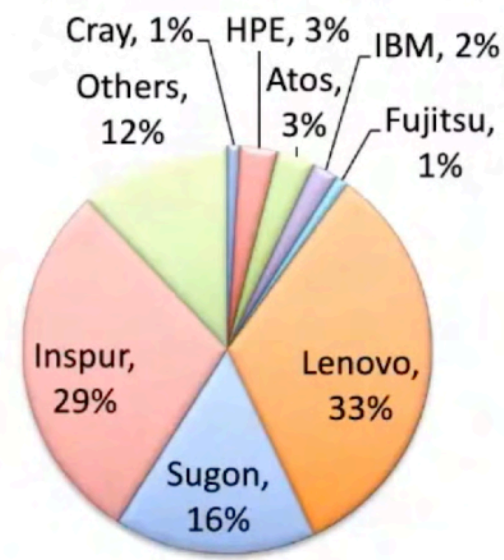
提供: 富士通株式会社

For detail see Jack Dongarra's report at: http://bit.ly/fugaku-report

China leads #Top500 Systems

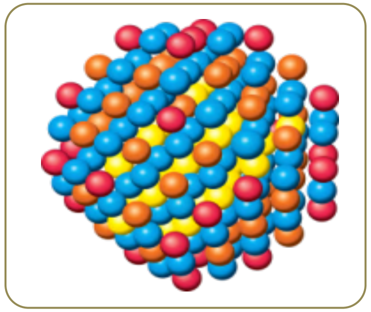




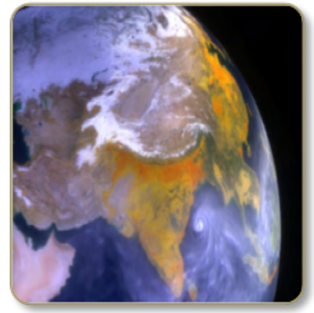


Research **Commercial**

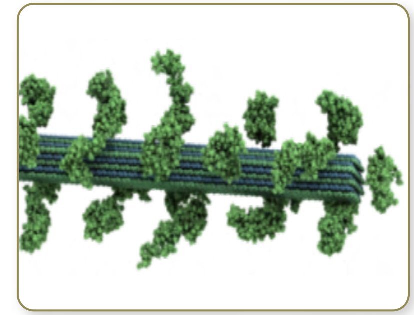
Science Applications



Material Science (WL-LSMS)
Role of material disorder, statistics & fluctuations in nanoscale materials & systems.

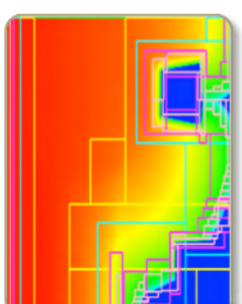


Climate Change (CAM-SE)
Realistic climate change adaptation & mitigation scenarios: precipitation & tropical storm patterns/statistics.



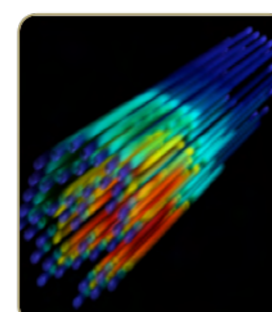
Biofuels (LAMMPS)
Multiple function molecular dynamics

Astrophysics (NRDF)
Radiation transport for astrophysics, laser fusion, combustion, atmospheric dynamics & medical imaging.



Combustion (S3D)
Combustion simulations to enable next generation diesel/bio-fuels to burn more efficiently.

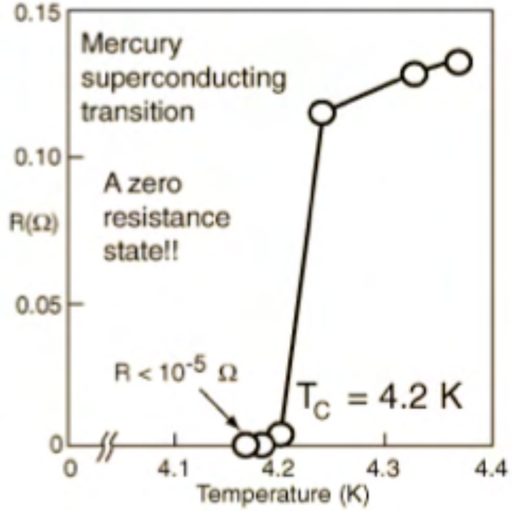
Nuclear Energy (Denovo)
Calculate Radiation transport for nuclear energy & technology apps.



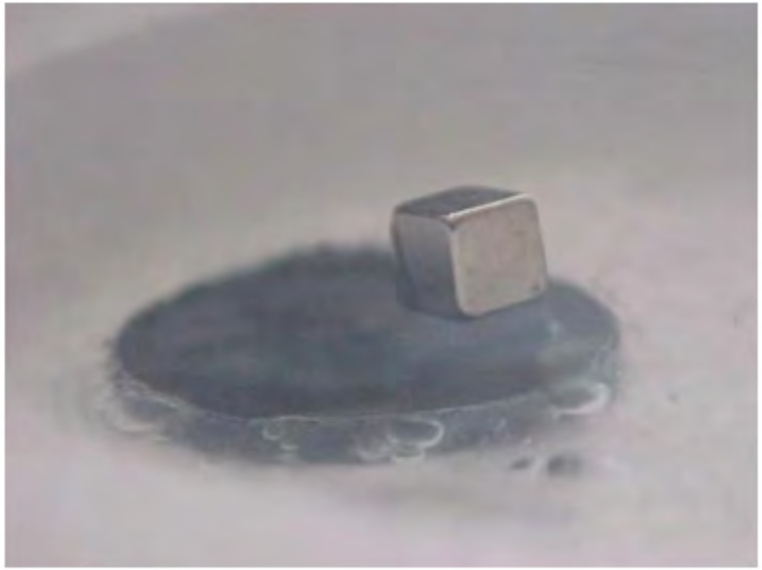
Superconductivity: a state of matter with zero electrical resistivity

Discovery 1911

Heike Kamerlingh Onnes (1853-1926)



Superconductor repels magnetic field
Meissner and Ochsenfeld, Berlin 1933



Microscopic Theory for Superconductivity 1957

PHYSICAL REVIEW VOLUME 108, NUMBER 5 DECEMBER 1, 1957

Theory of Superconductivity*

J. Bardeen, L. N. Cooper,† and J. R. Schrieffer‡
Department of Physics, University of Illinois, Urbana, Illinois

(Received July 8, 1957)

A theory of superconductivity is presented, based on the fact that the interaction between electrons resulting from virtual exchange of phonons is attractive when the energy difference between the electrons states involved is less than the phonon energy, $\hbar\omega$. It is favorable to form a superconducting phase when this attractive interaction dominates the repulsive screened Coulomb interaction. The normal phase is described by the Bloch individual-particle model. The ground state of a superconductor, formed from a linear combination of normal state configurations in which electrons are virtually excited in pairs of opposite spin and momentum, is lower in energy than the normal state by amount proportional to an average $(\hbar\omega)^2$, consistent with the isotope effect. A mutually orthogonal set of excited states in one-to-one correspondence with those of the normal phase is obtained by specifying occupation of certain Bloch states and by using the rest to form a linear combination of virtual pair configurations. The theory yields a second-order phase transition and a Meissner effect in the form suggested by Pippard. Calculated values of specific heats and penetration depths and their temperature variation are in good agreement with experiment. There is an energy gap for individual-particle excitations which decreases from about $3.5kT_c$ at $T=0°K$ to zero at T_c. Tables of matrix elements of single-particle operators between the excited-state superconducting wave functions, useful for perturbation expansions and calculations of transition probabilities, are given.

BCS Theory generally accepted in the early 1970s

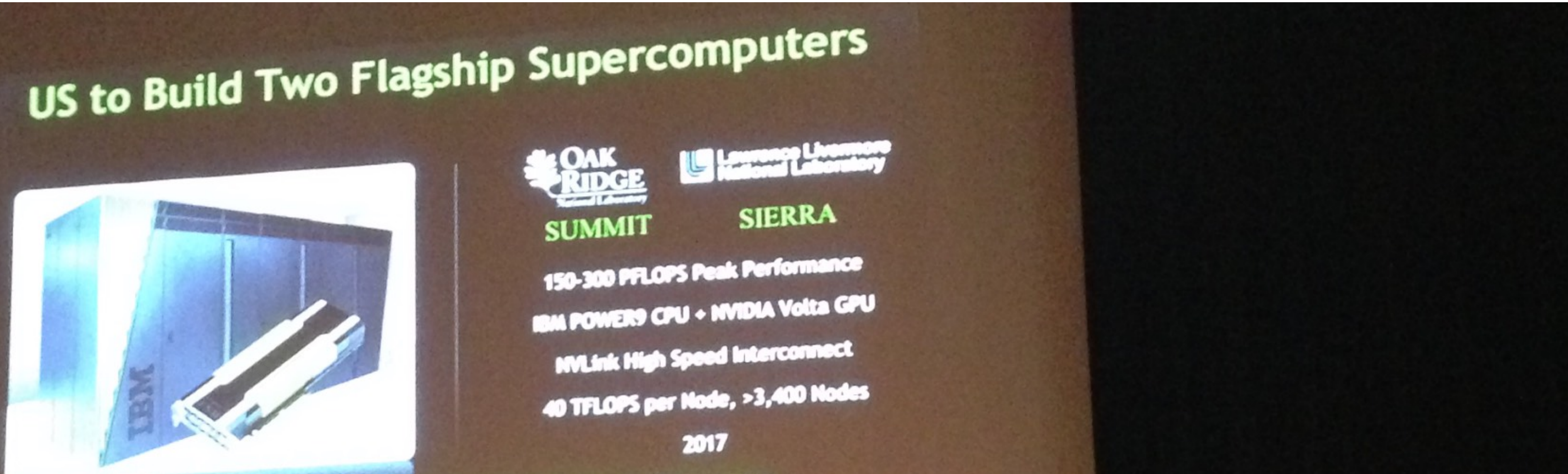
Courtesy of Thomas Schulthe

Who?

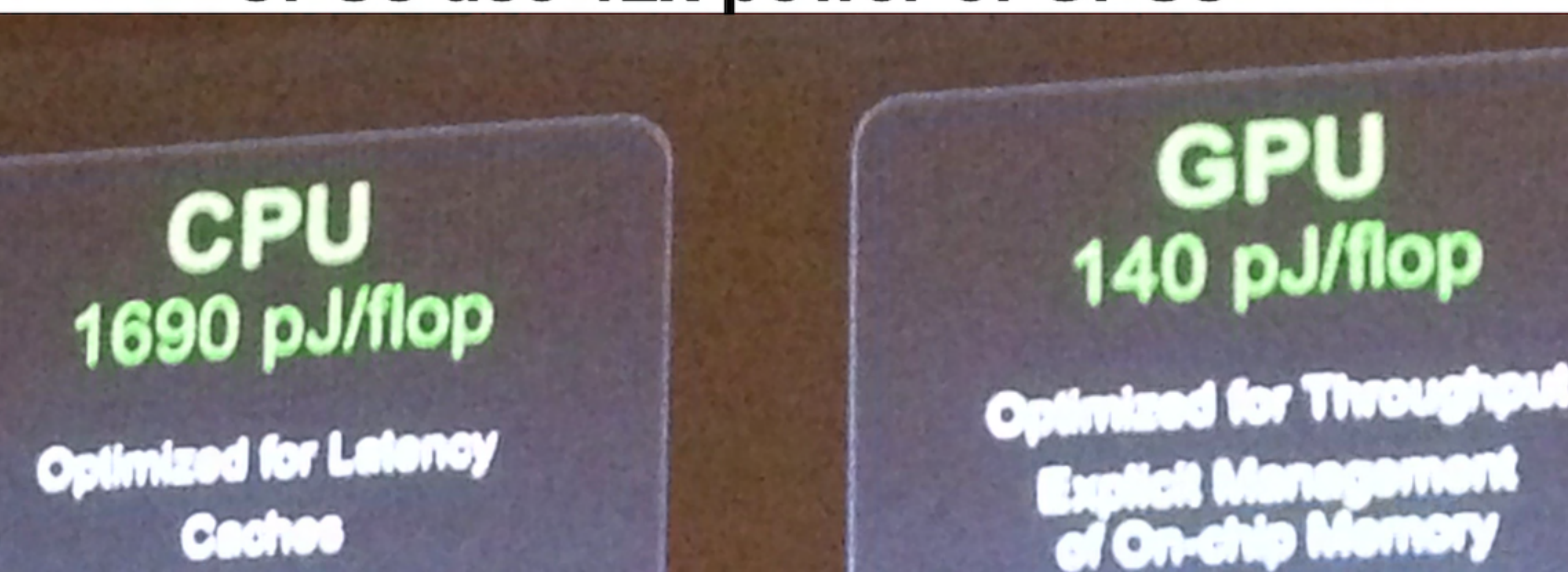
New algorithm to enable 1+ PFlop/s sustained performance in simulations of disorder effects in high-T_c superconductors

Models, Methods, & Implementation	T. A. Maier P. R. C. Kent T. C. Schulthess G. Alvarez M. S. Summers E. F. D'Azevedo	Physics Software Comp. mathematics
Map to Hardware	J. S. Meredith	Computer Science
Operations	M. Eisenbach D. E. Maxwell	Computer Center
System design	J. M. Larkin J. Levesque	Hardware vendor

Bill Dally NVIDIA Chief Scientist, Stanford Prof
HiPEAC'15 Keynote Amsterdam Jan 19, 2015

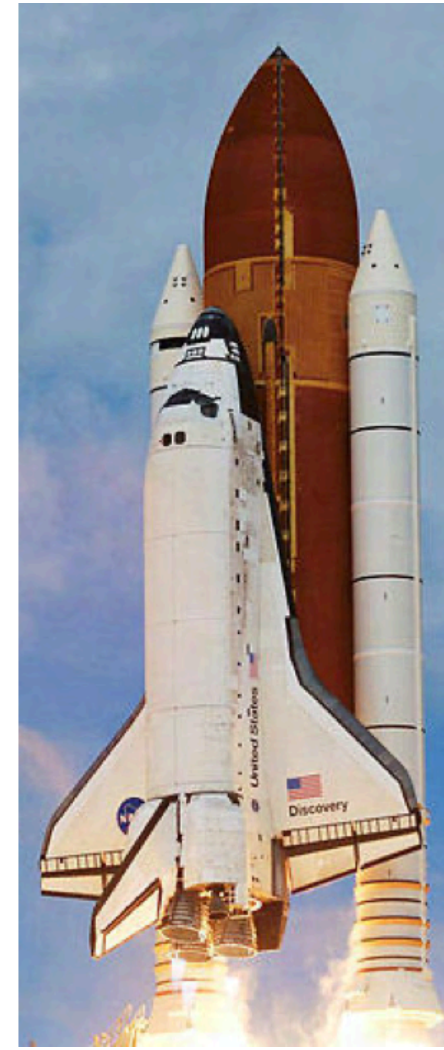


CPUs use 12x power of GPUs



Summit

Summary



GREAT Life after Langley! Opportunities, travel …

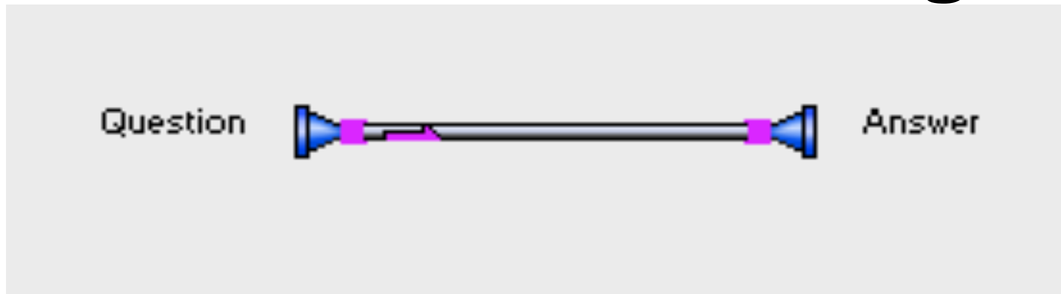
Exciting Supercomputer research: 10^15 speedup

Efficient GF/W: 2 ('15) => 15 ('21)

Exaflop Future: Frontier(GPUs), Fugatu(ARM) + ?

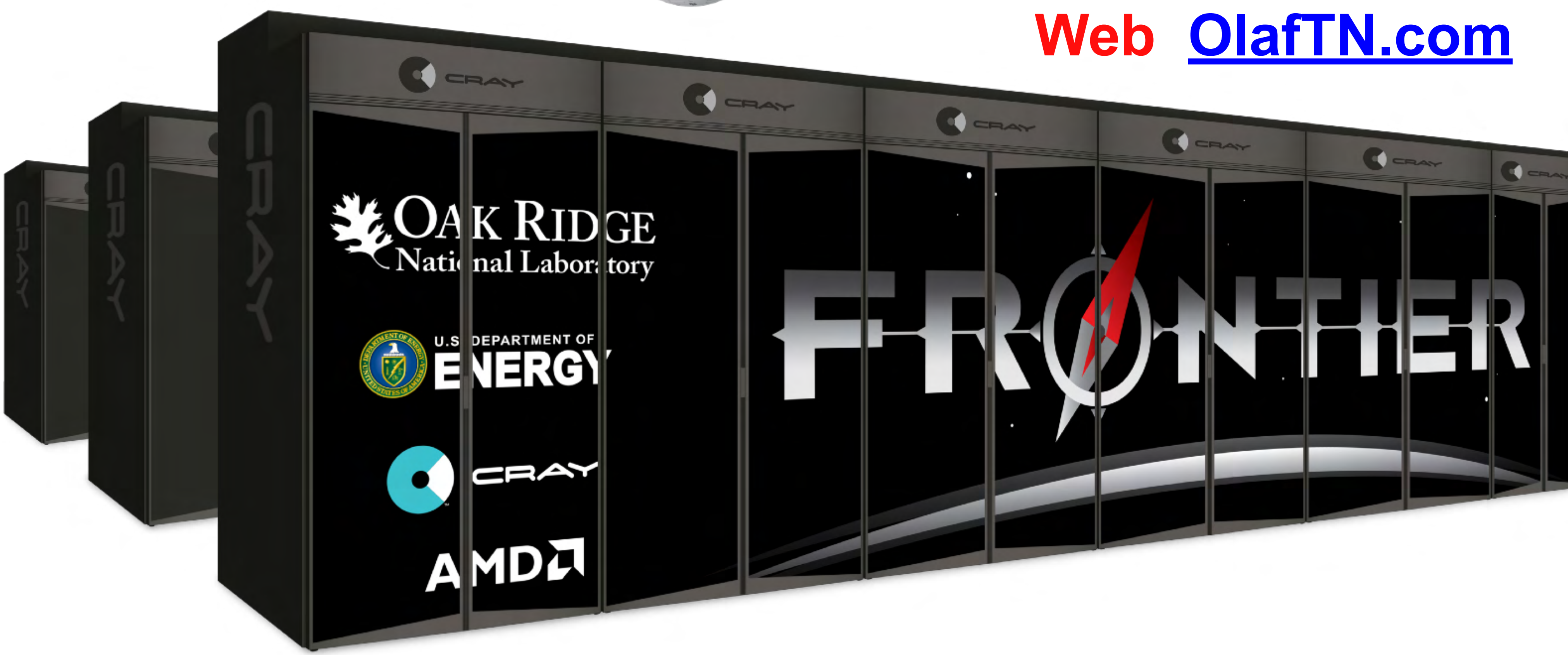
Change is Good! ***Who moved the cheese?***

Thanks for listening!



Contact Google Storaasli E-MAIL Olaf@cox.net

Web OlafTN.com



Credits: NASA, ORNL, Top500

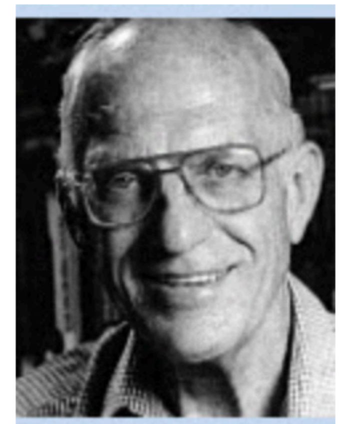
Additional Slides
(not used)

Developer of Finite Element Analysis Method Ray Clough Dies

BY Staff

November 10, 2016

Distinguished Members   earthquake engineering   finite element method   Ray Clough   structural analysis


Clough

Ray William Clough, Ph.D., P.E., NAE, Dist.M.ASCE, renowned as a developer of the finite element method for structural analysis of buildings, has died. He was 96.

Clough was professor emeritus of civil and environmental engineering at the University of California, Berkeley. He was a faculty member at Berkeley's Department of Civil and Environmental Engineering from 1949 to 1987, and served as Earthquake Engineering Research Center director from 1973 to 1977.

It was on a sabbatical leave in Trondheim, Norway, in 1956-57, that Clough developed the theories that would become the finite element method. He coauthored a paper in 1956 outlining the method, forever changing the field of structural analysis and the design of buildings and other structures.

In the 1960s, Clough had the vision to see how powerful computers could be in conducting structural analyses on giant structures. He published a series of papers that became the basis for commercial computer programs, now industry standards. His paper, "Dynamics of

Top10 Supercomputers Nov 2020

Rank (previous)	Rmax Rpeak (PFLOPS)	Name	Model	CPU cores	Accelerator (e.g. GPU) cores	Interconnect	Manufacturer	Site country	Year	Operat syste
1	442.010 537.212	Fugaku	Supercomputer Fugaku	158,976 × 48 A64FX @2.2 GHz	0	Tofu interconnect D	Fujitsu	RIKEN Center for Computational Science Japan	2020	Linux (RHEL
2▼ (1)	148.600 200.795	Summit	IBM Power System AC922	9,216 × 22 POWER9 @3.07 GHz	27,648 × 80 Tesla V100	InfiniBand EDR	IBM	Oak Ridge National Laboratory United States	2018	Linux (RHEL
3▼ (2)	94.640 125.712	Sierra	IBM Power System S922LC	8,640 × 22 POWER9 @3.1 GHz	17,280 × 80 Tesla V100	InfiniBand EDR	IBM	Lawrence Livermore National Laboratory United States	2018	Linux (RHEL
4▼ (3)	93.015 125.436	Sunway TaihuLight	Sunway MPP	40,960 × 260 SW26010 @1.45 GHz	0	Sunway[26]	NRCPC	National Supercomputing Center in Wuxi China[26]	2016	Linux (Raise)
5▲ (7)	63.460 79.215	Selene	Nvidia	1,120 × 64 Epyc 7742 @2.25 GHz	4,480 × 108 Ampere A100	Mellanox HDR Infiniband	Nvidia	Nvidia United States	2020	Linux (Ubunt
6▼ (5)	61.445 100.679	Tianhe-2A	TH-IVB-FEP	35,584 × 12 Xeon E5–2692 v2 @2.2 GHz	35,584 × 128 Matrix-2000[27]	TH Express-2	NUDT	National Supercomputer Center in Guangzhou China	2013	Linux (I
7▲ (new)	44.120 70.980	JUWELS (booster module)[28]	BullSequana XH2000	1,872 × 24 AMD EPYC 7402 @2.8 GHz	3,744 × 108 Ampere A100	Mellanox HDR Infiniband	ATOS	Forschungszentrum Jülich Germany	2020	Linux (CentO
8 ▼(6)	35.450 51.721	HPC5	Dell	3,640 × 24 Xeon Gold 6252 @2.1 GHz	7,280 × 80 Tesla V100	Mellanox HDR Infiniband	Dell EMC	Eni Italy	2020	Linux (CentO
9 ▼ (8)	23.516 38.746	Frontera	Dell C6420	16,016 × 28 Xeon Platinum 8280 @2.7 GHz	0	InfiniBand HDR	Dell EMC	Texas Advanced Computing Center United States	2019	Linux (CentO
10▲(new)	22.400 55.424	DAMMAM-7	CRAY CS-Storm	1,978 × Xeon Gold 6248 @2.5 GHz	7,912 × 80 Tesla V100	InfiniBand HDR 100	Cray	Saudi Aramco Saudi Arabia	2020	Linux (RHEL

Next: June Top10

#1 EF for HPL-AI (less precision)

15GF/W 1-3,5
6,3GF/W 4,6