An Introduction to High Performance Computing

http://www.cs.bris.ac.uk/Teaching/Resources/COMS30005/

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Prof Simon McIntosh-Smith

- Graduated as Valedictorian in Computer Science from Cardiff University in 1991
- Joined Inmos to work for David May as a microprocessor architect
- Moved to Pixelfusion in 1999 – a high-tech start-up designing the first GPGPU, a many-core general purpose graphics processor
- Co-founded ClearSpeed in 2002 as Director of Architecture and Applications
- Joined the CS department at the University of Bristol in April 2009 to focus on High Performance Computing. Currently running the £50m project to design and build the UK's next national HPC service, Archer2

Dr Gethin Williams

The University Of Sheffield.

Graduated with 1st class honours in Cognitive Science (Psychology & Computer Science) in 1995.

(Went cycling in Australia)

Gained a PhD in Computer Science (speech recognition) from Sheffield University in 1999.

(Went cycling in New Zealand)

2000-2004 Worked for several speech recognition start-up companies.

Joined the Geography department at the University of Bristol in 2004 to work on Climate Modelling.

University of BRISTOL

Now Research Computing Manager, running the Blue Crystal supercomputer for the university.

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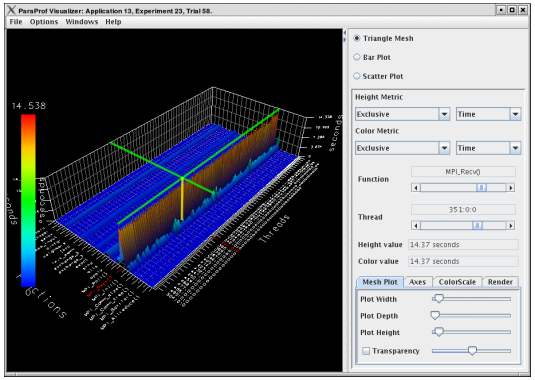
Course Goals

To provide an introduction to High Performance Computing (HPC), including:

- Hardware:
  - Computer architectures
  - Interconnects
  - Storage
- Software
  - Scaling to massive systems
  - Optimisation & Debugging
- Parallel programming
- Trends



A key theme throughout will be ***parallelism***

Assumptions and Prerequisites

- You're already decent programmers
- You're familiar with the C language
- You love playing with cutting-edge hardware
- You can "figure things out" yourself
- You're up for a challenge!

Course Outline

- 10 credit unit → **100 hours in TB1**
  - ~10 hours per week, or 2 hours per weekday
- Split into **40 hours for lectures and labs**, and **60 hours for coursework** and personal study
- Assessment is **100% coursework** based

Lab Classes

- These are a **core** part of the lectures
- Key parts of the material are presented in labs
- MVB 2.11 PC lab, Thursdays 11am-1pm
- Experienced lab assistants, all did the course
  - James Price, Tom Deakin, Matt Martineau, George Pawelczak, Patrick Atkinson & Andrei Poenaru






Course Timetable

- **Two assessments, both using BlueCrystal:**
  1. **Optimising serial code**
  2. **Programming a multi-core shared memory system with OpenMP**
- ***You need to register for an account on BlueCrystal by the end this Tuesday to be ready for the lab this Thursday***
- Not everything we teach you will be assessed
- But **all of it** will be useful and important in your future

Course Timetable

• **Week 1-4**	4 weeks	Serial	25%
• **Week 5-11**	7 weeks	OpenMP	75%

- Deadlines all **5pm on the Friday**
  - Deadlines at end of weeks 4 and 11

- **PLAN** your time to avoid deadline clashes with other units!!!
- Don't leave things to the last minute…

Resources

- **Blue Crystal phase 3 (~£2m):**
  - ~5,500 cores, >100 TFLOP/s
  - ~320 nodes, dual 2.6 GHz Intel 8-core processors (Intel Xeon E5-2670 CPUs)
  - 64 GB memory/node
  - Infiniband high-speed network
  - IBM's General Parallel File System (GPFS)
  - Petascale storage system (~1000TB)
- Accelerator technologies:
  - 76x NVIDIA K20 Tesla GPGPUs
  - 8x Intel Xeon Phi 5110P
  - 4x AMD S9150 GPGPUs

See: https://www.acrc.bris.ac.uk/acrc/phase3_user_guide/phase3_user_guide3.htm

What is High Performance Computing (HPC) all about?

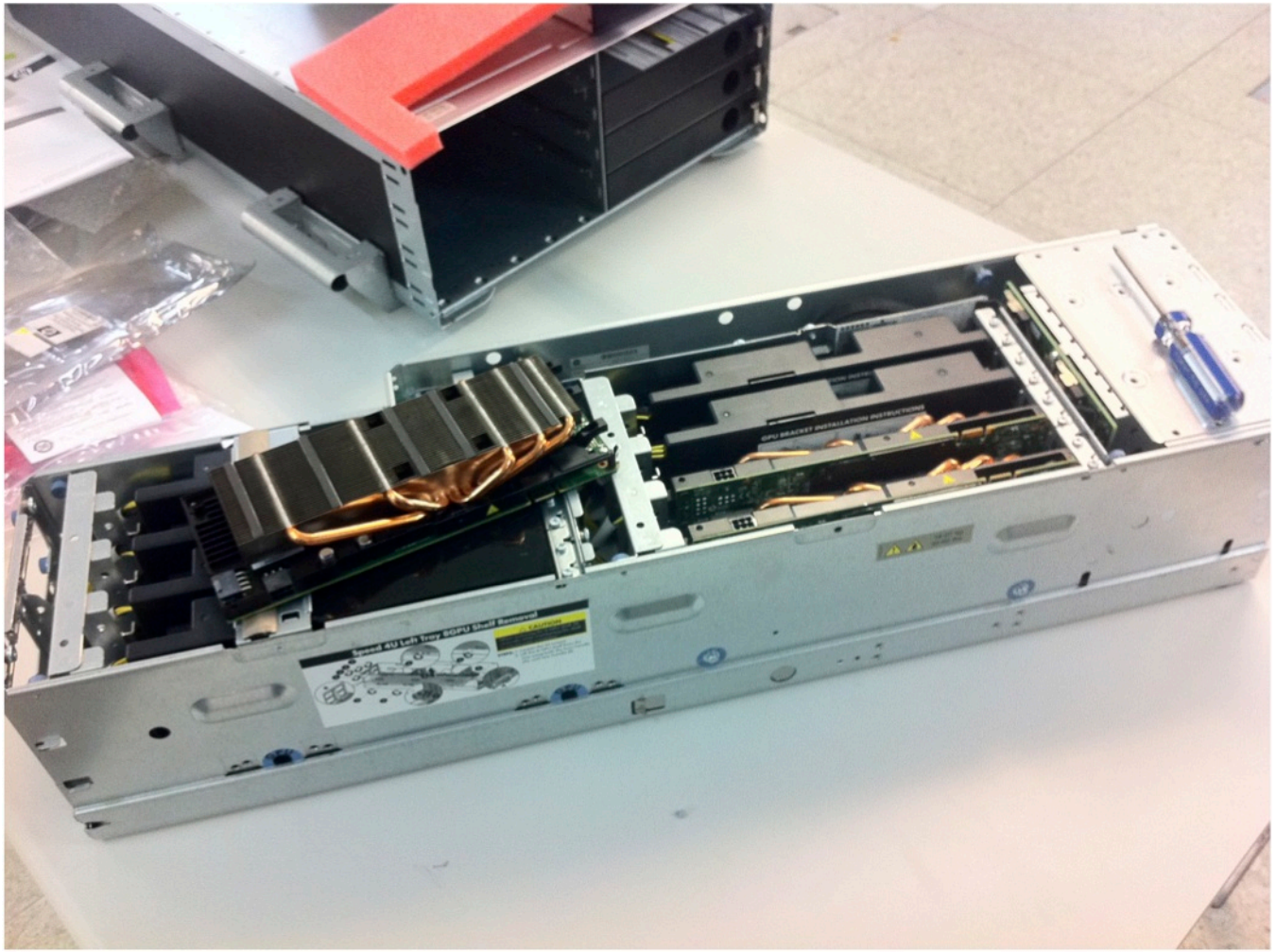
Harnessing computers with millions of cores

Sunway TaihuLight at NSC in China (fastest in the world)

- 93.01 PetaFLOPS (93.01×10^{15}), 40,960 CPUs
- 10,649,600 cores, $273M, 15 MW

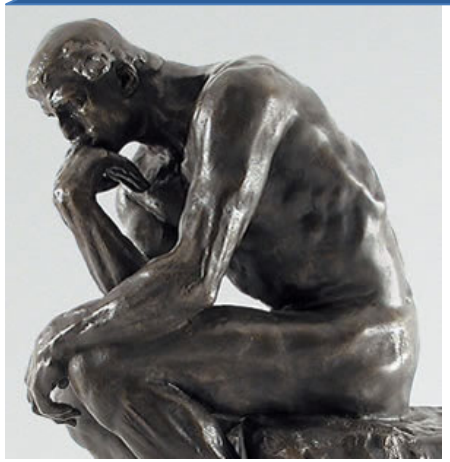
Top500: http://top500.org

Heterogeneous Hardware



HP server – 2 CPUs and 8 GPUs in one node

Science



Theory Simulation Experiment

Motivation:

HPC is driving ***breakthroughs*** in

Climate

Physics

Medicine

Chemistry

Engineering

Aero

Arts

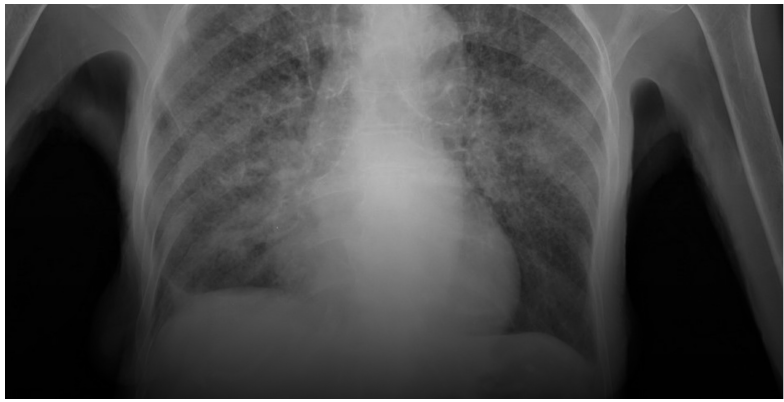
Mathematics

Artificial intelligence

Artificial intelligence

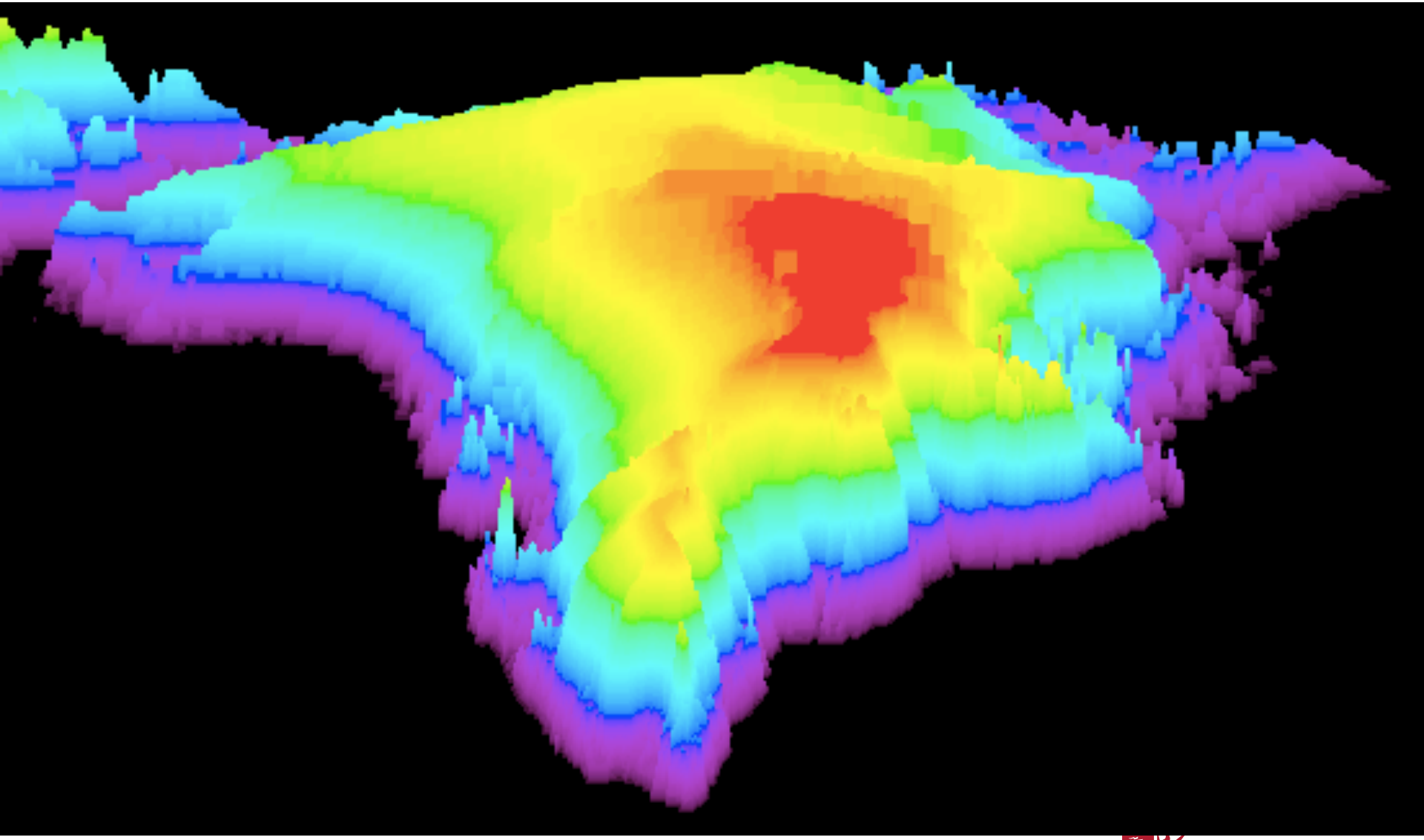
HPC is enabling breakthroughs in AI in areas such as self driving cars, robotics, language translation, image recognition, medical diagnostics and many more

"HPC is supercharging AI. AI is the new electricity. It takes 10^{19} FLOPS, $100 of electricity, and 4TB of data to train a speech recognition system" – Dr Andy Ng, Baidu chief scientist

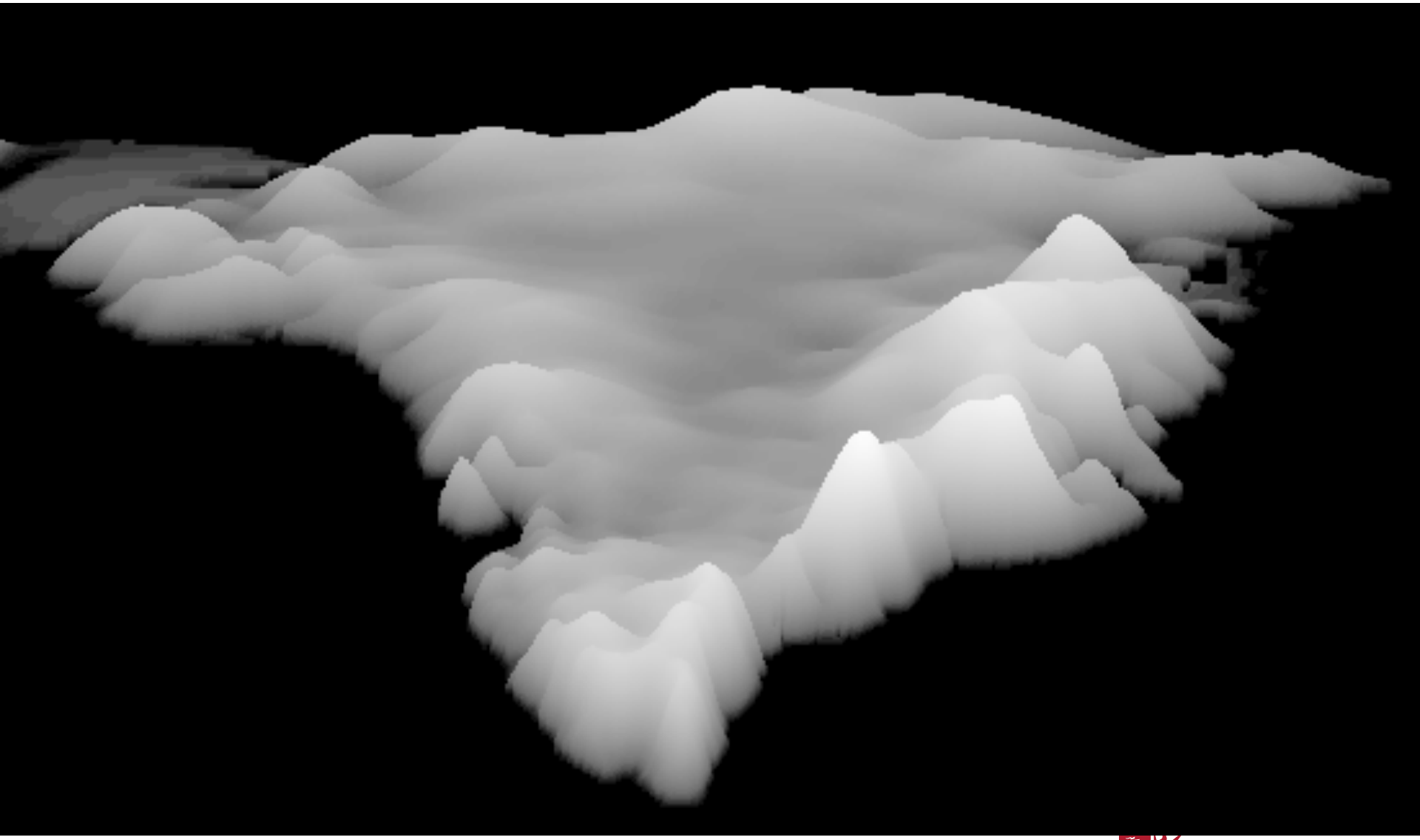


https://blogs.nvidia.com/blog/category/deep-learning/

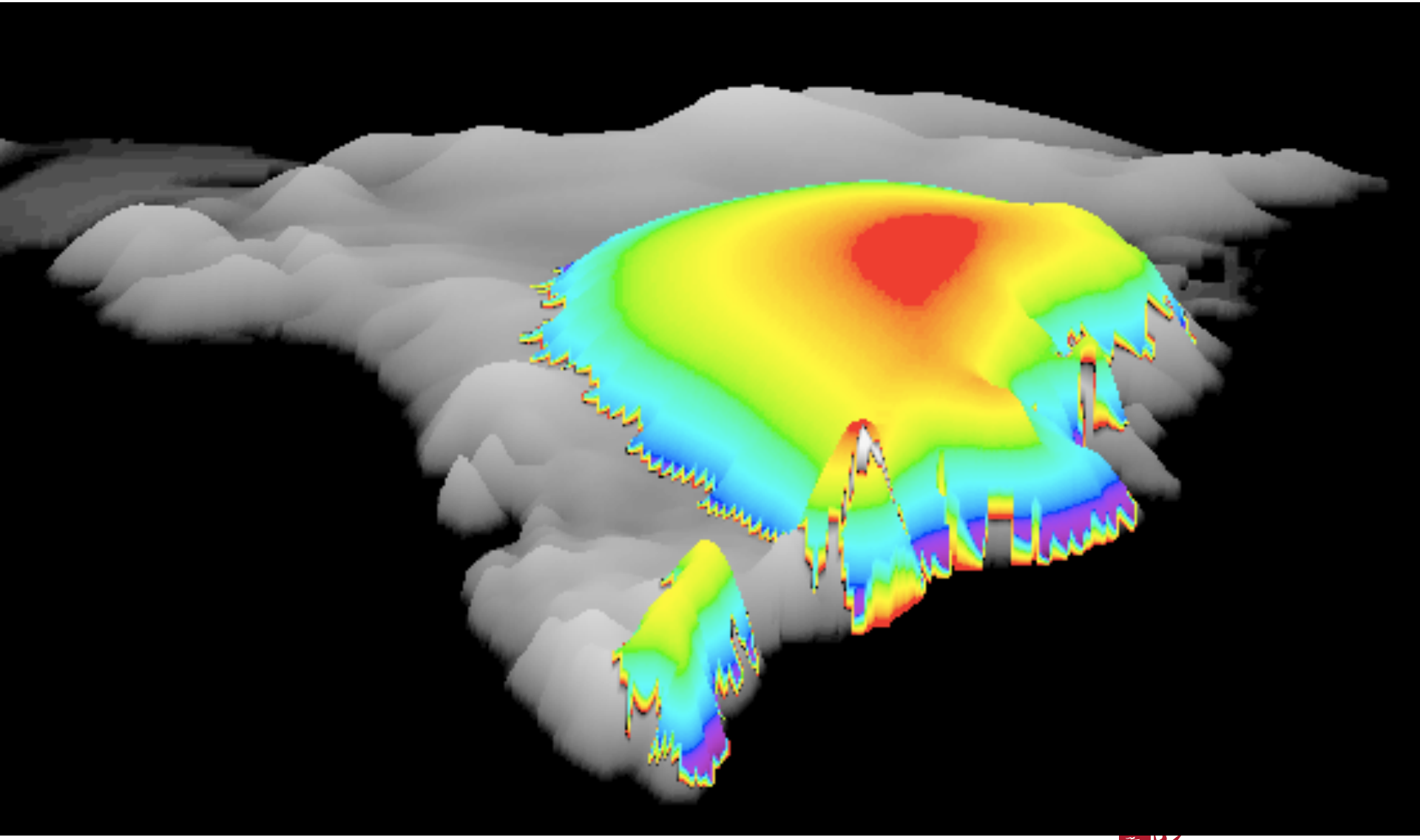
Earth systems modelling



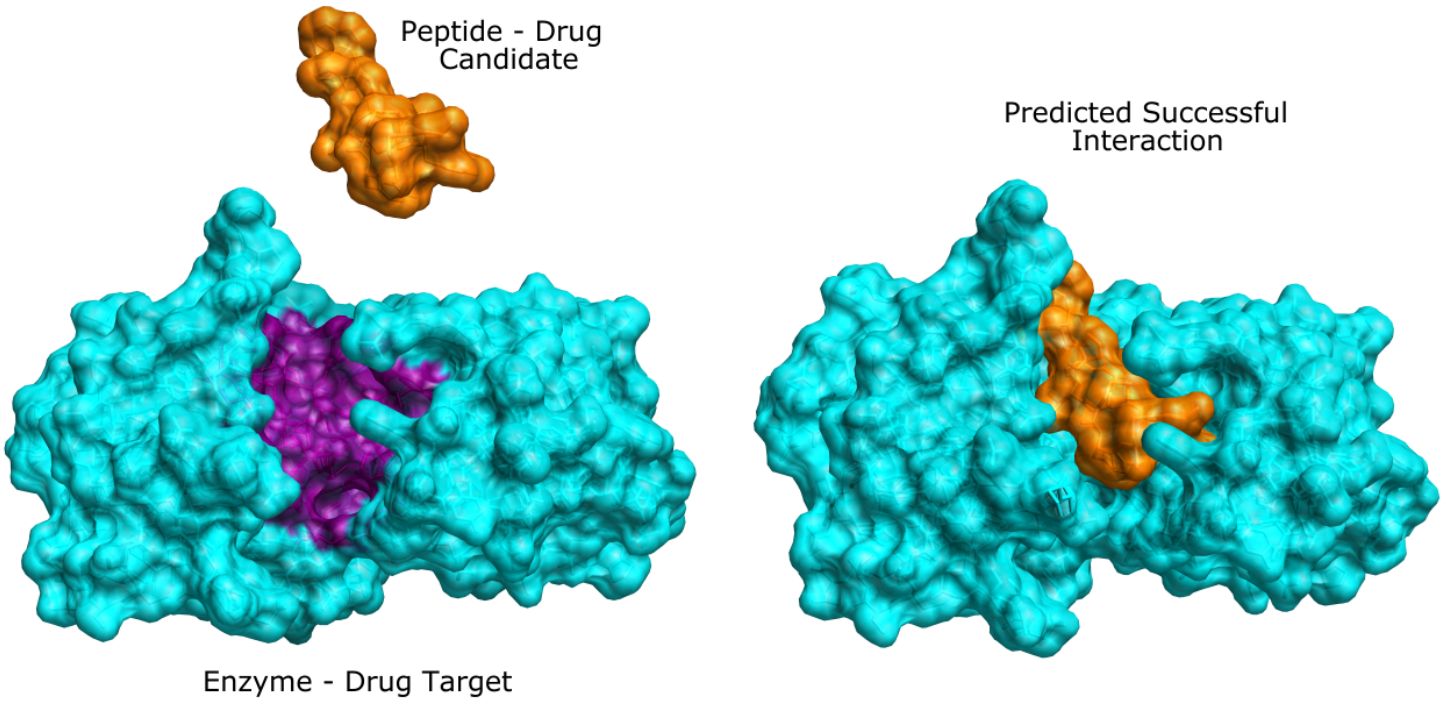
Earth systems modelling



Earth systems modelling



Life sciences



Drug docking simulations to find new therapies for Emphysema – work by Dr Richard Sessions, Biochemistry

Computational Fluid Dynamics

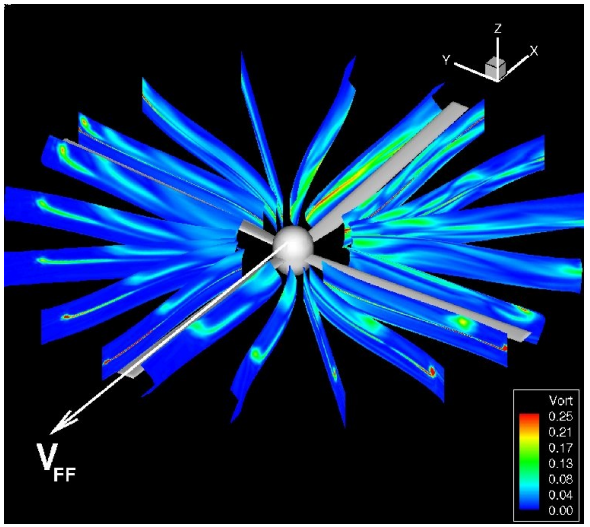
Investigating *unsteady flows and their interactions with deforming structures, particularly helicopter rotors.*

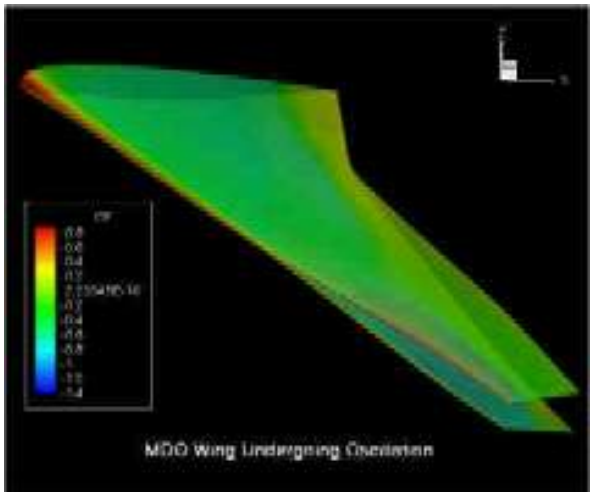
Aerodynamic optimisation.

Computational aero-servo-elastics.

Hypersonic vehicles.

Professor Chris Allen, Department of Aerospace Engineering.





AIRBUS
AN EADS COMPANY

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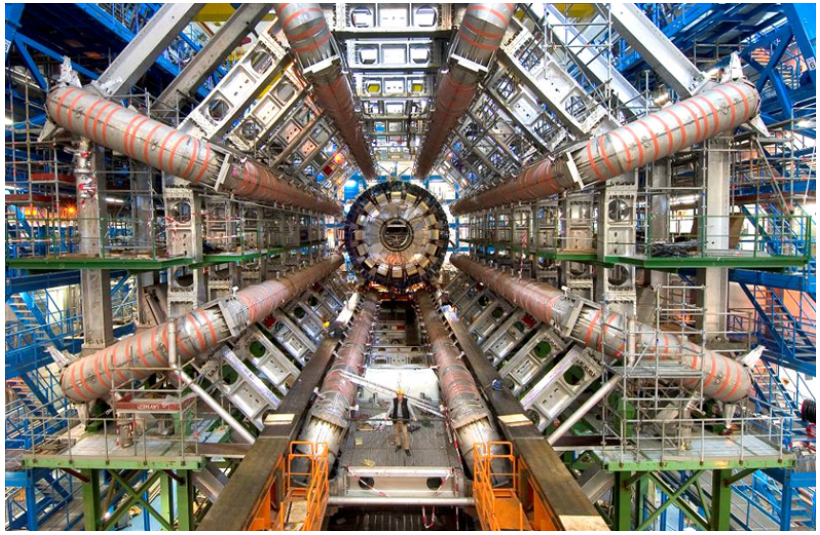
Particle Physics

Analysing the results from the ***Large Hadron Collider***, looking for the Higgs boson particle and seeking to understand why more matter than antimatter exists in the Universe.

Professor Nick Brook and Dr Dave Newbold, Department of Physics.



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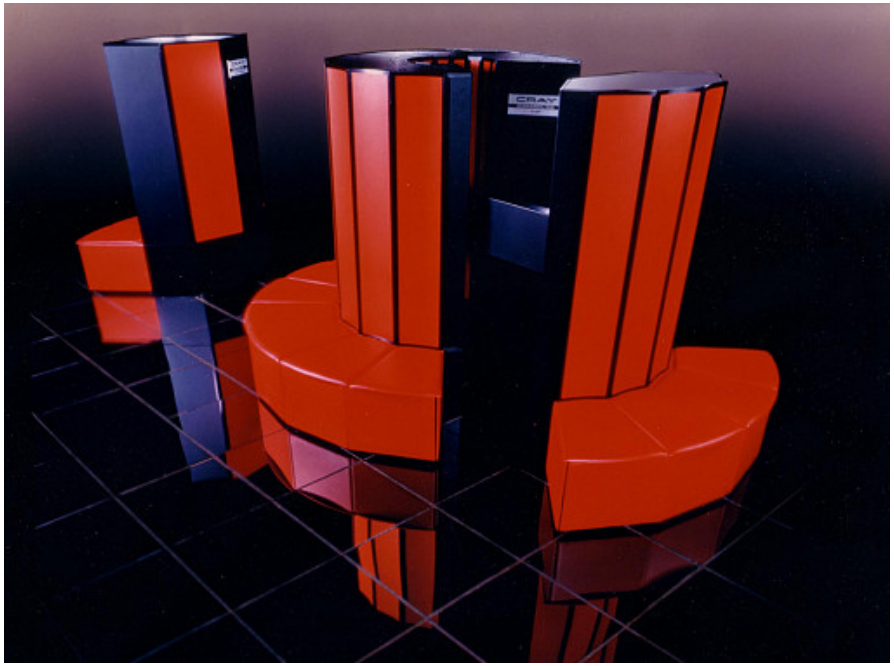
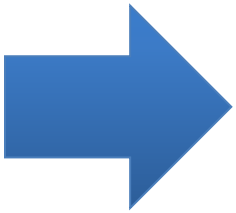
So HPC is all about "big computing?"

Not anymore





Cray X-MP, mid 1980's

Apple iPhone, 2007

Both approx. 1 GFLOP

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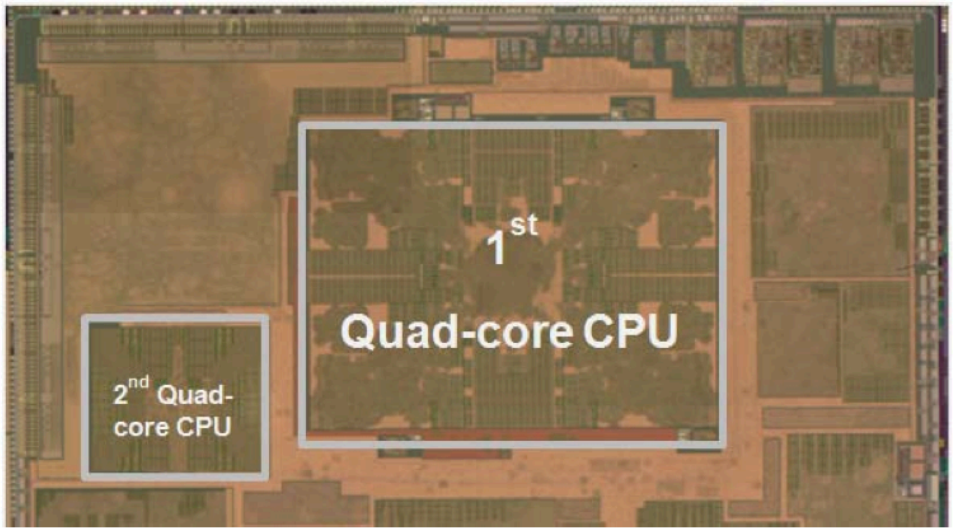
Mobile augmented reality

Pokémon Go

Mobile augmented reality

IKEA Place

Mobile supercomputing



Samsung Exynos 5 Octa

- 4 fast ARM cores and 4 energy efficient ARM cores
- Includes OpenCL programmable GPU

Almost all mobile devices are now powered by **parallel processors** and need **parallel programs**

Mobile supercomputing

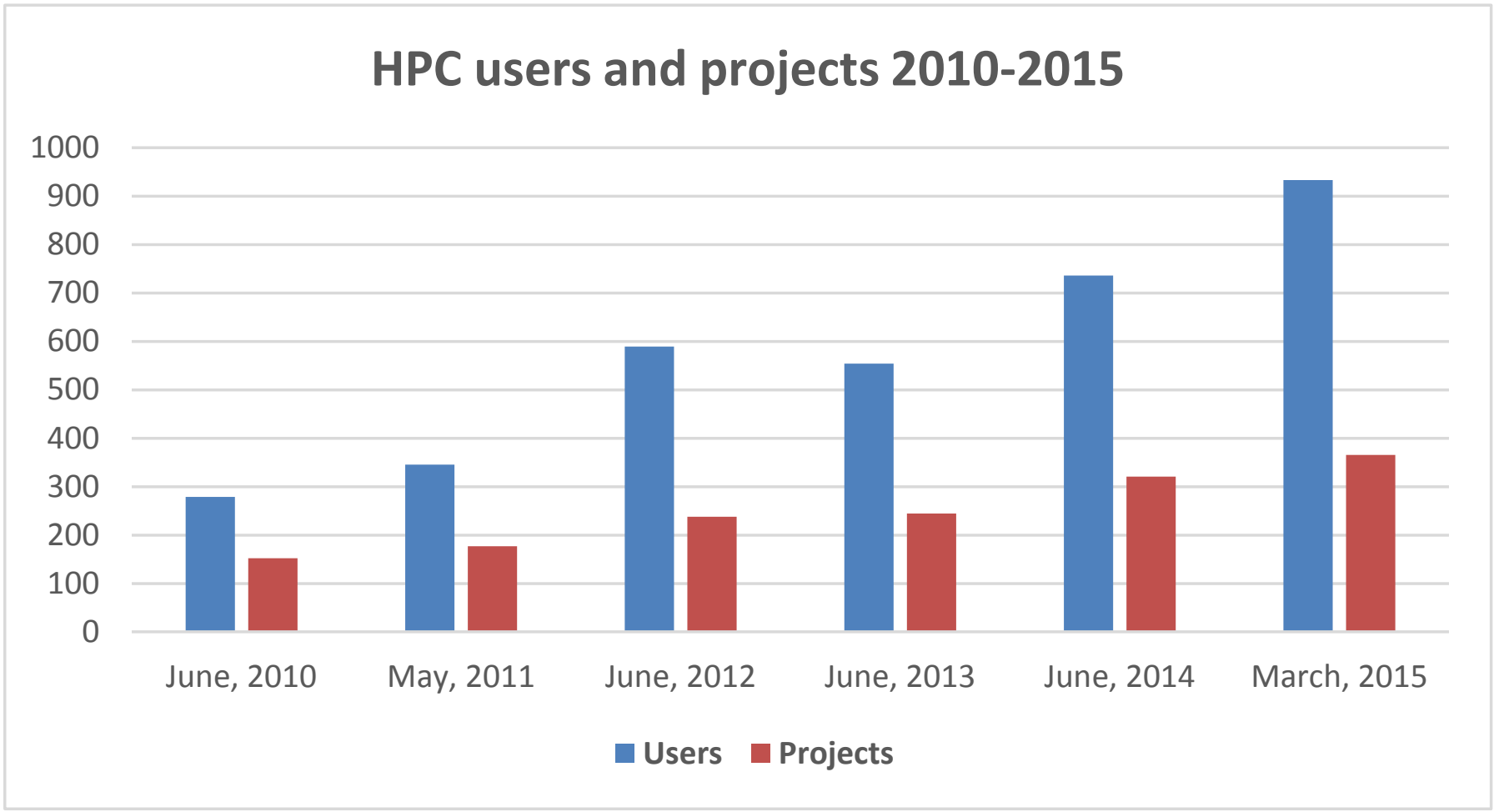
Summary

- **High Performance Computing** is enabling fundamental breakthroughs in science, engineering and medicine that will increasingly affect every person on the planet
- HPC is now mainstream, not a niche
- It embraces parallelism in hardware and software
- ***All*** processors are becoming both **highly parallel** and **heterogeneous**!

Further reading

- Find out about the Blue Crystal supercomputer:
  - https://www.acrc.bris.ac.uk
- Reading list available on the website:
  - http://www.cs.bris.ac.uk/Teaching/Resources/COMS30004/
- Take a look at the Top500:
  - http://www.top500.org

Bristol has a fast-growing HPC community



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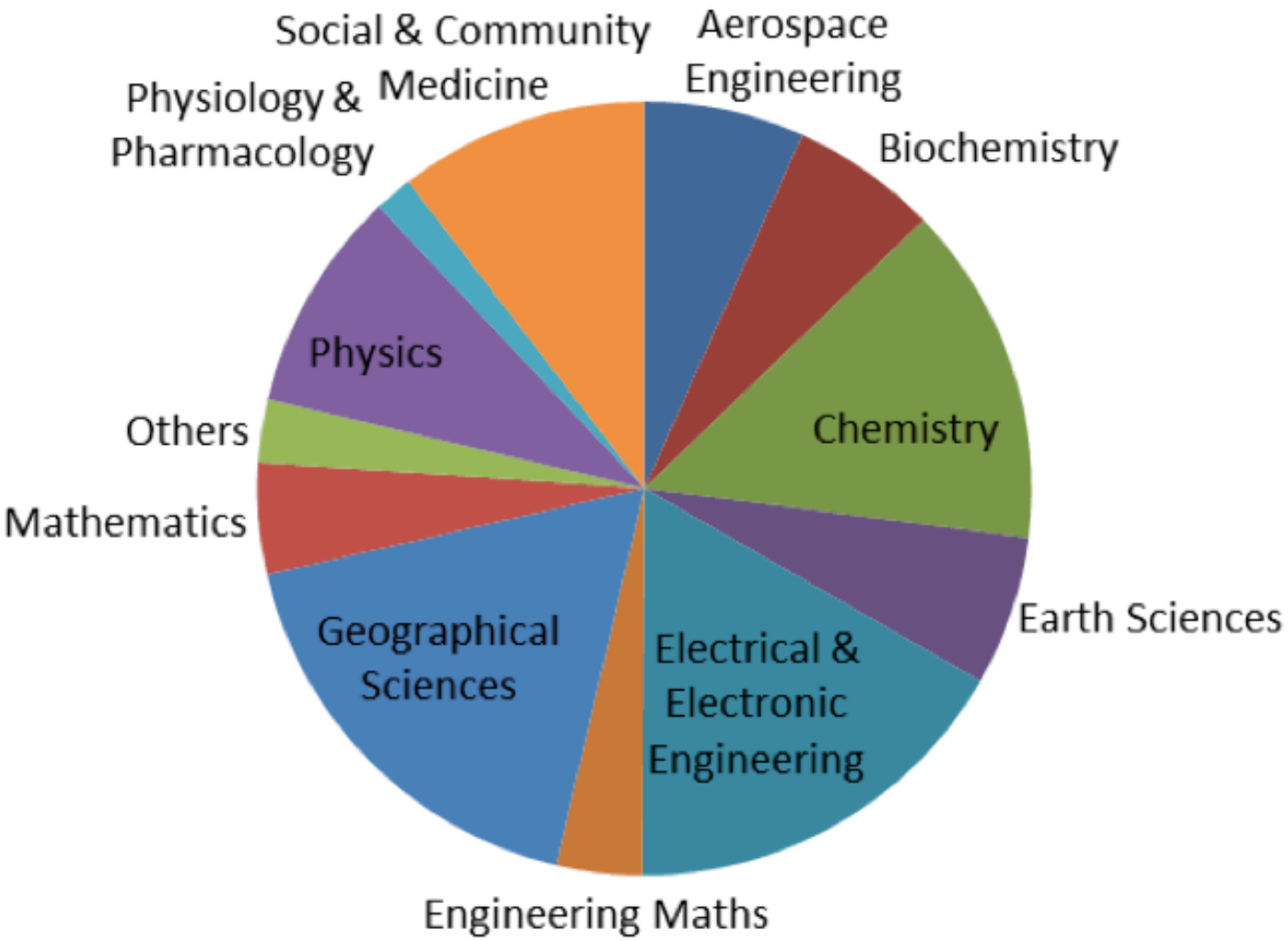
HPC used across research areas



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