THE CRESTA PROJECT

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Collaborative Research into Exascale Systemware, Tools and Applications - CRESTA

- Exascale Sc
- 39 months - 2014
  - Leading Eu owners and
    - EPCC –
    - HLRS – ity – Abo, Finland
    - CSC – E - Jyvaskyla,
    - KTH – St
  - A world lea ndon –UK
    - Cray UK UK
  - World lead Paris, France
    - Technisc many
    (Vampir) eden
    - Allinea L Germany

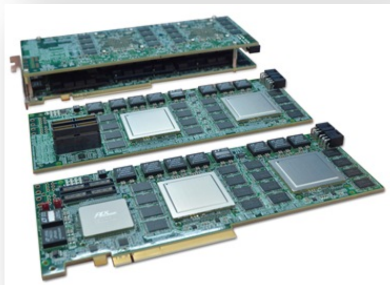
A hardware *and* software challenge

- Based on current technology roadmaps Exascale systems will be impossible to build below 50MW
  - GPUs and Xeon Phi plus traditional multi-core microprocessors, memory hierarchies and even with embedded i... ...cannot get to 20MW
- The Exascale exp... ...ern data flow hierarchies insid... ...a well balanced com...
- The solution... ...ler processors w... communicati...
- But these solution... ...arallelism
  - Today's leader scales to 92 mi... ...and 526MW at the Exascale
- Slower better balanced cores mean parallelism at the 500 million – 1 billion thread scale

Hardware is leaving software behind – we don't know how to use such parallelism

Lowering the energy requirements

- Most energy efficient supercomputer today is Japanese Shoubo system from RIKEN
  - 7.031 GigaFLOPS per watt
- Would require
  - 3.3 **BILLION** cores to deliver an ExaFLOP
  - 142 Megawatts
- Current target by 2025
  - 20 Megawatts
  - 200-500 million cores
- BUT … we have no idea how to use such systems for modelling and simulation
- Exascale is a **SOFTWARE** challenge



At the Exascale software leaves algorithms behind

- Few mathematical algorithms are designed with parallelism in mind
    - … parallelism is “just a matter of implementation” is the mind-set
- This approach gener… as components are custom-built for …
    - … but the year… …ange and users are relucta… …riting takes place
- HPC is at a “t…
    - Without fun… …many areas will be limited … and… …systems
    - But it’s not just a cas… …tions – it’s much more difficult
- This doesn’t just apply to Exascale – it’s apparent at the Petascale too
- CRESTA tackled this challenge head on

Software and how we model and simulate remain the key Exascale challenges

Key principles behind CRESTA

- Two strand project
  - Building and exploring appropriate
  - Enabling a set of key *co-design* ap
- Co-design was at the heart of the
  - provided guidance and feedback to
  - integrated and benefited from this develo
- Employed both incremental and disruptive solutions
  - Exascale requires approaches
  - Particularly true for
  - Solutions
- Project has
  and new so
  and case s

Disruptive approach

- Work with co-design applications to consider alternative algorithms
- Crucial we understand maximum performance before very major application redesigns undertaken

Incremental approach

- Through optimisations, performance modelling and co-design application feedback
- Look to achieve maximum performance at Exascale and understand limitations e.g. through sub-domains, overlap of compute and comms

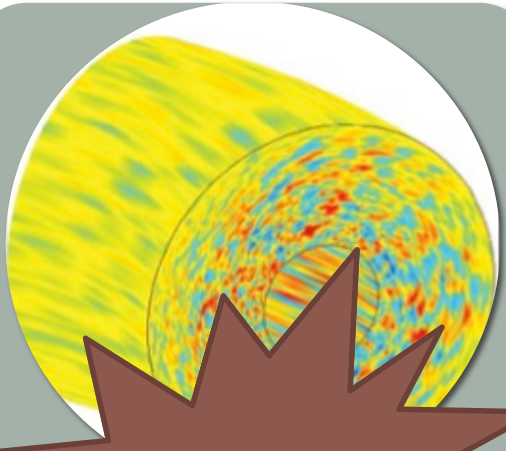
Where are we on the road to Exascale?

- The call text from 2010 said:

> The target is to develop a small number of advanced computing platforms with potential for extreme performance (100 petaflop/s in 2014 with potential for exascale by 2020), as well as optimised application codes driven by the computational needs of science and engineering and of today's grand challenges such as climate change, energy, industrial design and manufacturing, systems biology. These platforms should rely on vendors' proprietary hardware or on COTS.

- The fastest machine in Europe is 6.3 Petaflops Linpack today
- The fastest machine in the World is 33.9 Petaflops Linpack today

Co-design applications

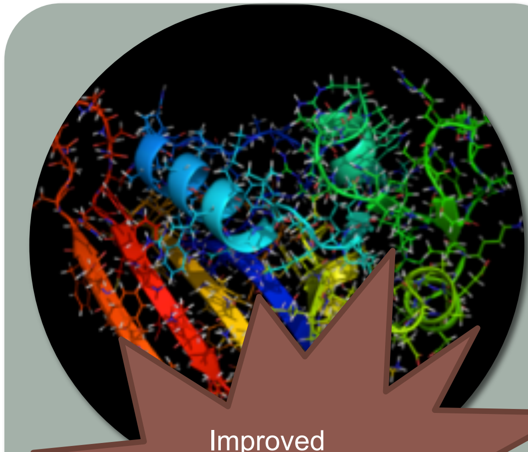


Exascale 3D decomposition and visualisation

Elm

Gy ... nt
fu
Simula ... sma behavior in large s ale fusion reactors

An almost complete code restructuring
Radical reduction of memory consumption per core



Improved implementations + code reorg for task parallelism + ensemble engine

G

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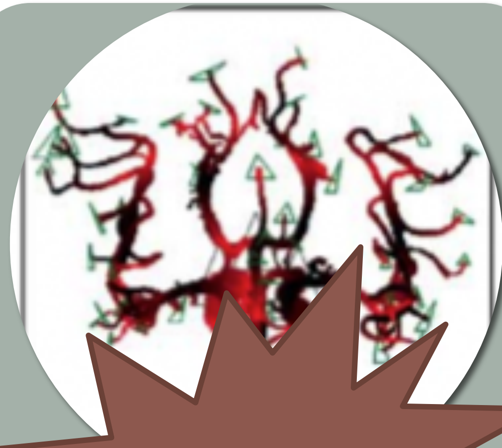
- ...mputational material and drug design

10M atom simulation

Coupling strong scaling techniques with ensemble scaling



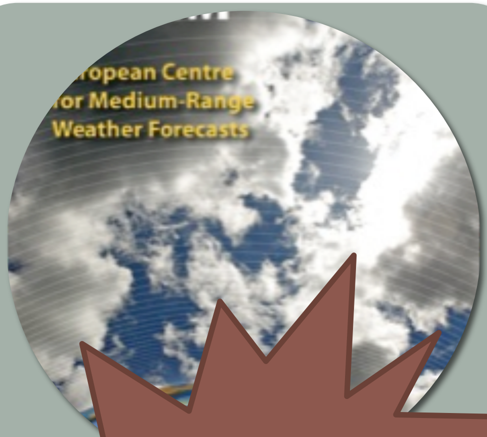
Physics for Exascale + performance / scaling of LB

H

S ... ovascular
... LB
Med ... simulations to help surg ries
Brain aneurysm simulation

Pre- and post-processing and load balancing
Hybridisation, restructuring

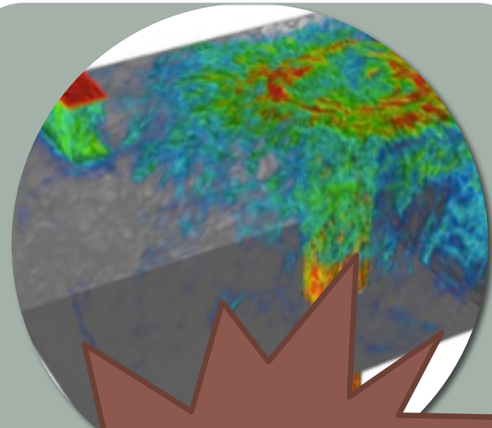
Co-design applications



PGAS approaches + cubic grid + OmpSs experiments

IFS ... ction
Th ... weather
... ve lives
Simu ... ng the trajectory of hurricane Sandy

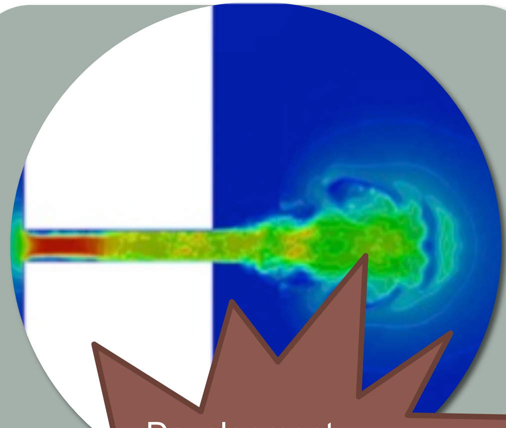
Acceleration
Task-graph based parallelization
New communication models



GPGPU engine + AMR + Exascale mesh partitioner

N ...
S ... on Mira
... lant cooling
simu ... ons

Adaptive mesh refinement acceleration

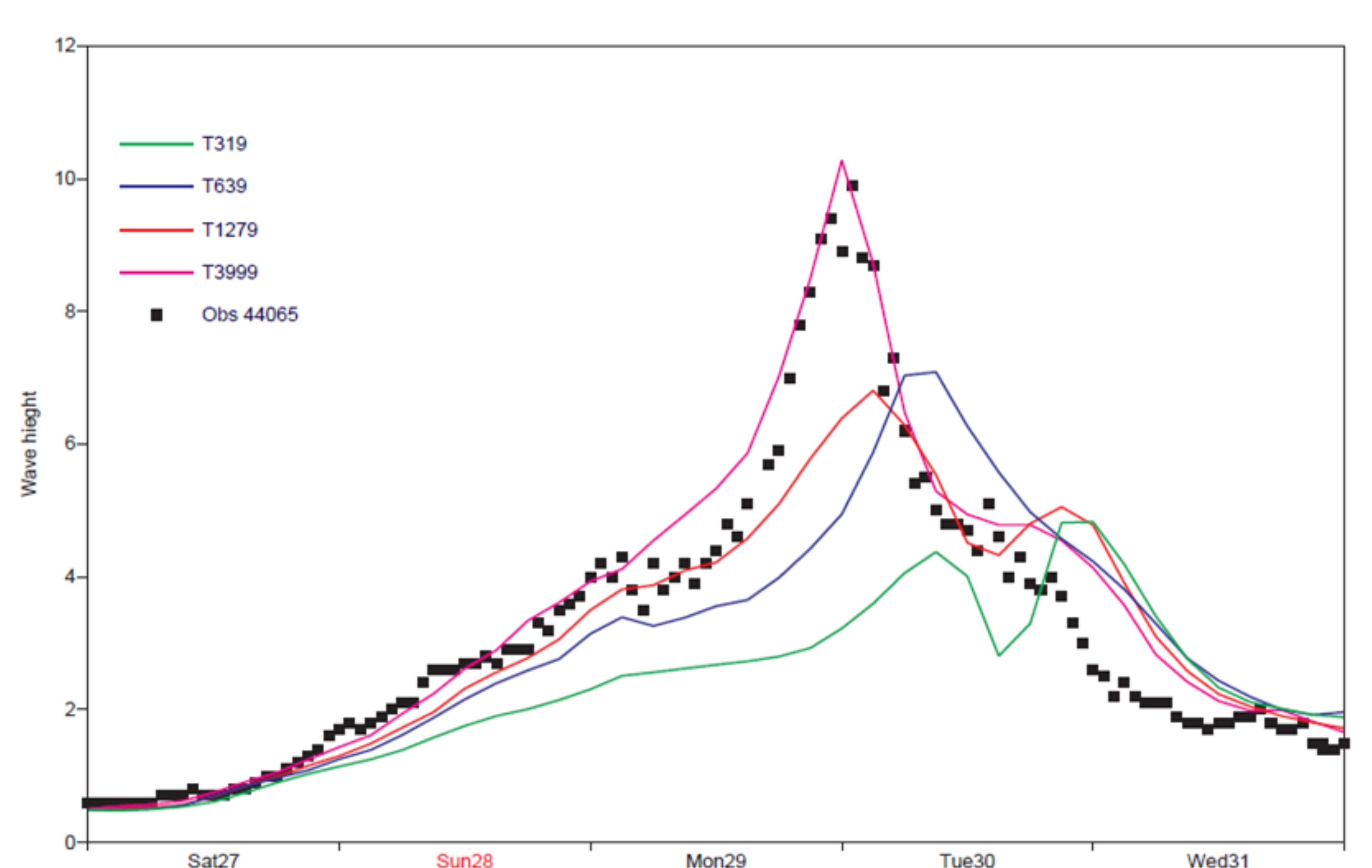


Development stopped – OpenFOAM is **NOT** an Exascale code

... fine
... pace and time
Wi ... turbines, hydroelectric power plants
Francis pump turbine simulation

Linear solver optimization

Why high resolution modelling is important



October 2012

Achievements

- We showed how software co-design can work
  - Driven by a general understanding of the scale of parallelism that Exascale hardware will deliver
- Identified many challenges – not just with parallelism but also I/O performance, tools, libraries – software and systemware
- Made tools advances which also benefit Petascale
- Shown that some codes e.g. OpenFoam will never run at the Exascale in their present form
- Given code owners the space to explore the Exascale and plan how to respond to it e.g. the ECMWF scaling team
- A key success was been to create awareness of the challenges – so that all of us can properly plan – **SOFTWARE IS THE KEY**