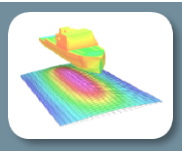
opera simulation software

COBHAM

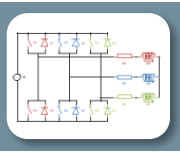


FEA ANALYSIS

General-purpose multi-physics design and analysis software for a wide range of applications

OPTIMIZER

Automatically selects and manages multiple goal-seeking algorithms



INTEROPERABILITY

Built-in circuit modelling and interfaces to leading CAD packages

SERVICE

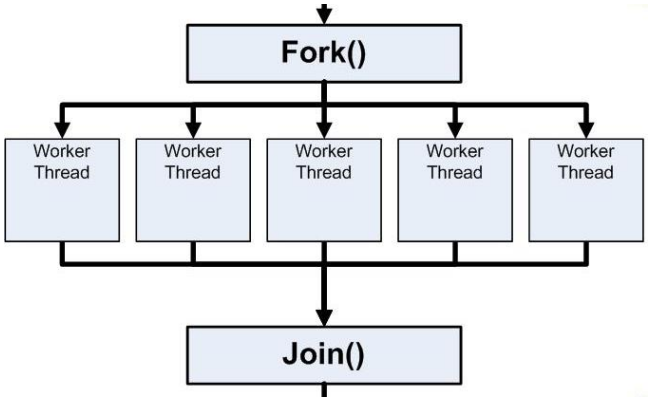
Technical support, training and consultancy services available for software usage and applications

Parallel processing in Opera 16

By Nigel Atkinson

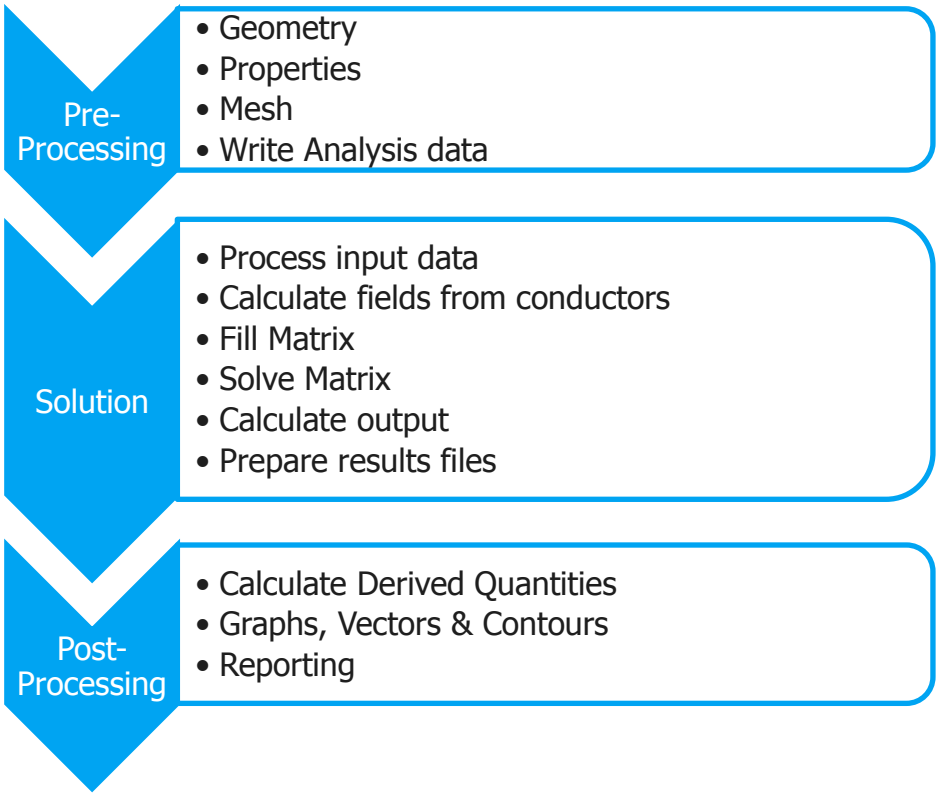
What do we mean by parallel processing?

"In general, parallel processing means that at least two microprocessors handle parts of an overall task. The concept is pretty simple: A computer scientist divides a complex problem into component parts using special software specifically designed for the task. He or she then assigns each component part to a dedicated processor. Each processor solves its part of the overall computational problem. The software reassembles the data to reach the end conclusion of the original complex problem."



The FEA process

- **Regardless of product, or physics, certain aspects of the Finite Element Analysis process are common**
- **Certain aspects can be parallelised, others have too many dependencies to be practical**



CPU and/or GPU?

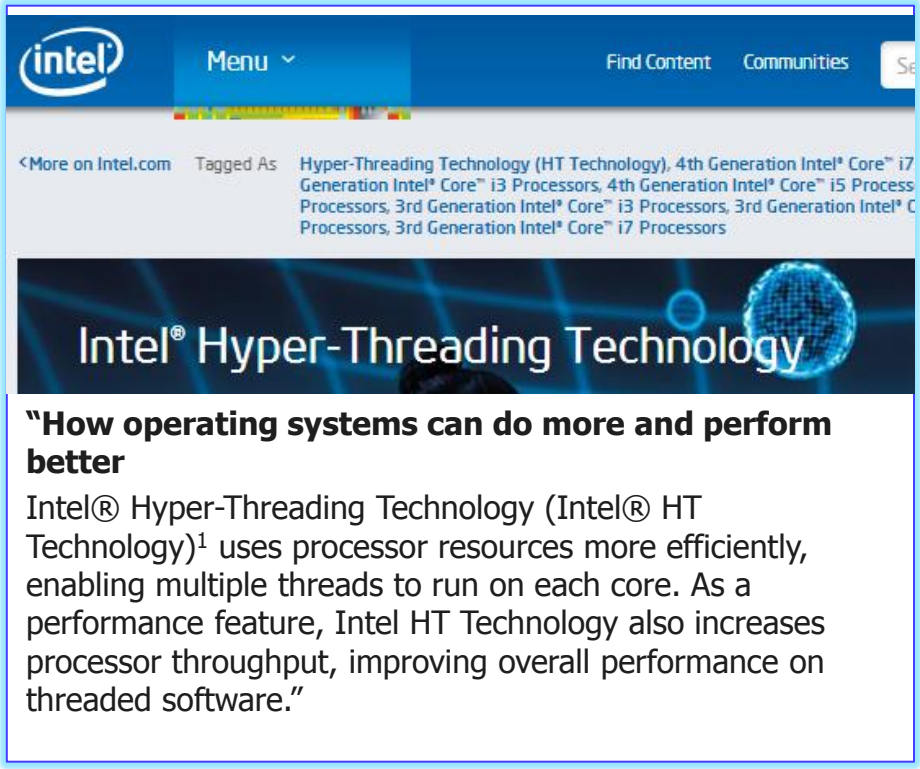
- **The first task – decide on a platform**

- **CPUs have a small number of advanced intelligent cores**
- **GPUs have a large number of very simple cores**

- **In version 16 we are supporting multi-core CPUs in a Shared Memory configuration**

- **No GPU implementation at this time**
- **GPUs are good for a limited number of very repetitive simple tasks**

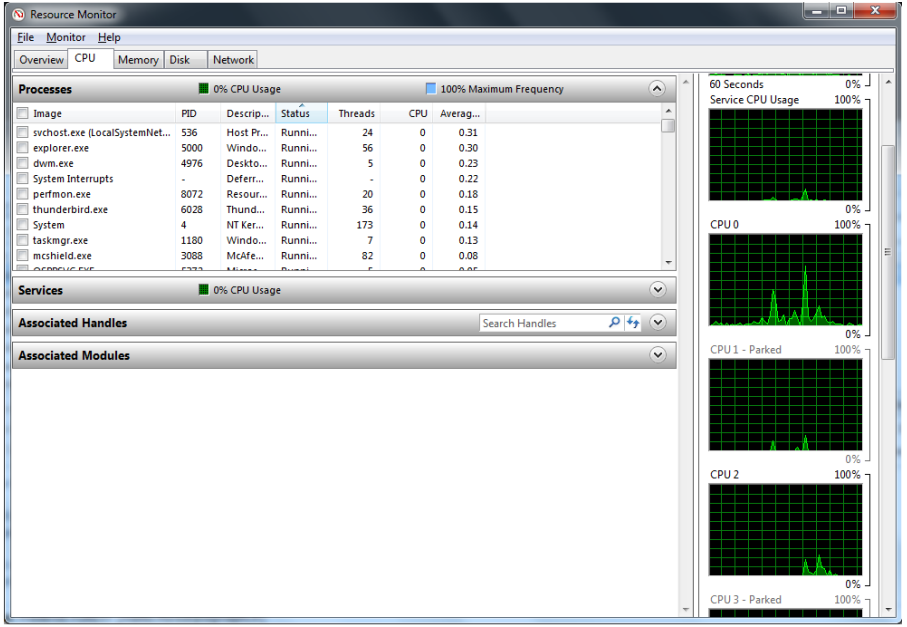
Hyper-threading



"How operating systems can do more and perform better

Intel® Hyper-Threading Technology (Intel® HT Technology)[1] uses processor resources more efficiently, enabling multiple threads to run on each core. As a performance feature, Intel HT Technology also increases processor throughput, improving overall performance on threaded software."

- **If you have Hyper-threading enabled you will see more cores than you physically have**



What do we mean by thread-safe?

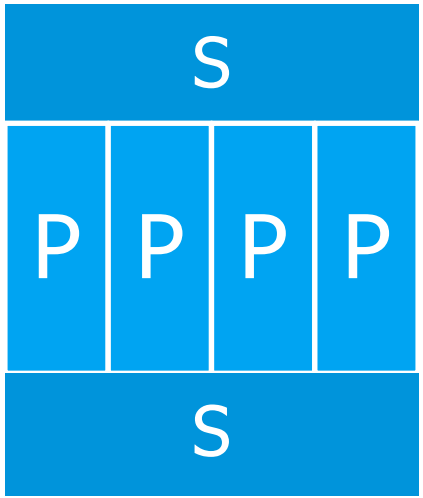
- **Thread Safety is an absolute requirement for parallel processing**

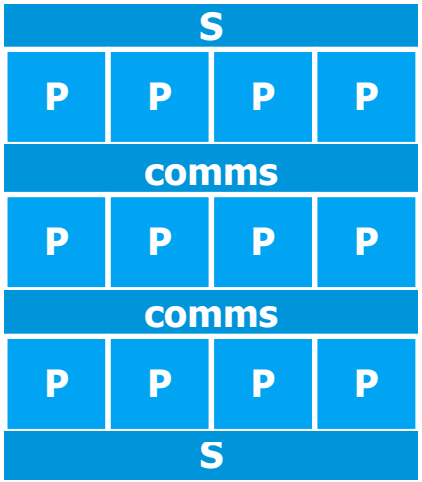
- **"A program [or subroutine] is thread-safe if it has no indeterminacy in the face of any multithreading scenario"**

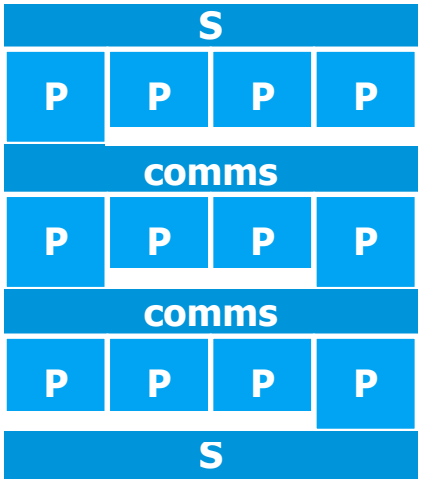
- **"A subroutine is thread-safe if it manipulates shared data in such a way that it guarantees safe execution by multiple threads at the same time"**

Granularity

- **Granularity is the ratio of computation to communication**
  - Coarse Granularity = small number of large tasks
  - Fine Granularity = large number of small tasks
- **Trade-off between parallelism speed-up and communication overhead**







Coil Field Calculations

COBHAM opera simulation software

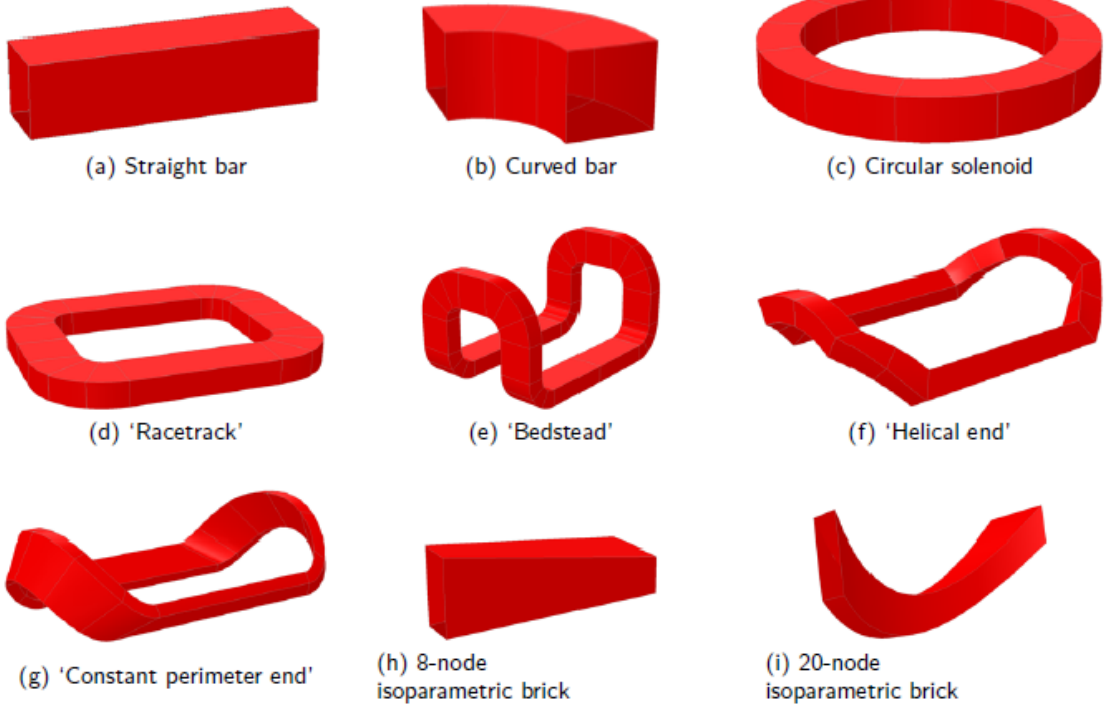
- The magnetic field B at position r_p due to a volume V with current density J is given by the Biot-Savart integral

$$\mathbf{B}(\mathbf{r}_p) = \frac{\mu_0}{4\pi} \int_V \frac{\mathbf{J} \times \mathbf{R}}{R^3} \mathrm{d}V$$

  - μ_0 is the permeability of free space,
  - $\mathbf{R} = \mathbf{r}_p - \mathbf{r}$ is the displacement between the field point $\mathbf{r}_p$ and the source point $\mathbf{r}$, and
  - $R = |\mathbf{R}|$.

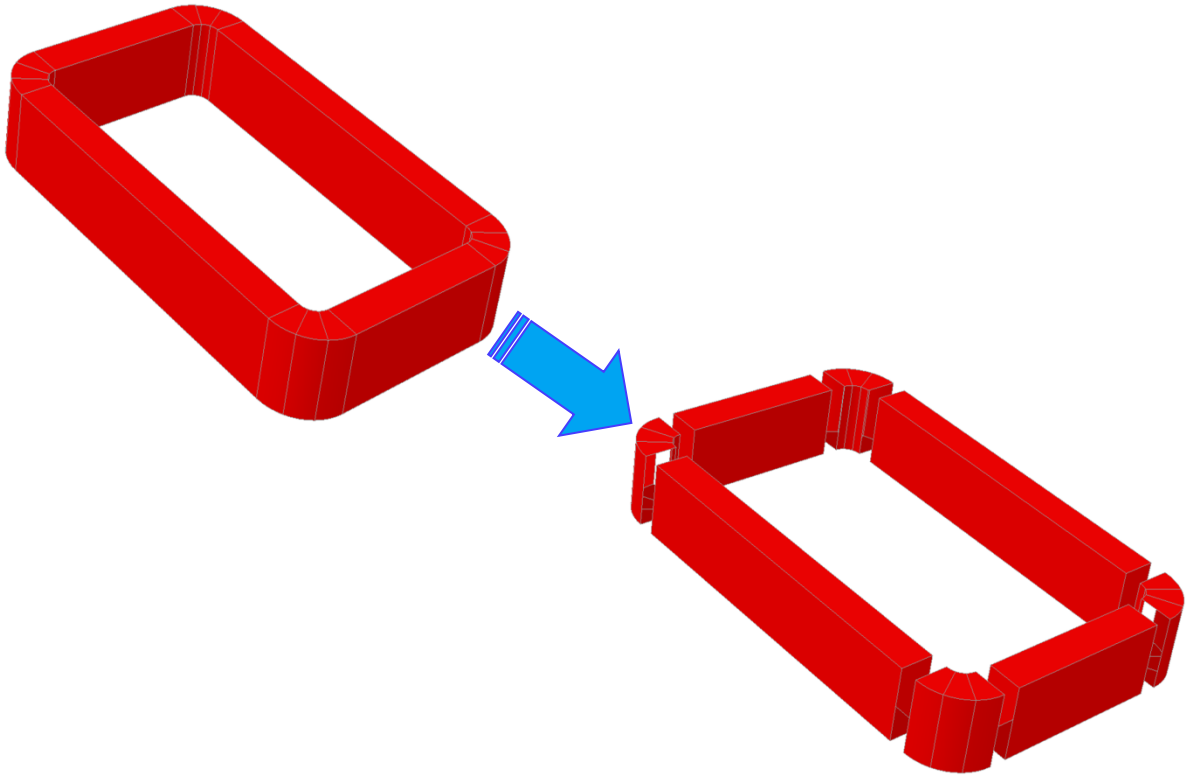
- Implemented using our conductor library
- Chosen for first parallel implementation because:
- Field at **each point** is **independent**
- Field due to **all** the **conductors** is the **sum** of the fields due to **each conductor**

Opera Conductors



- We first create new Fortran types for each kind of conductor.
- We then use different instances of those types for each conductor in the model.
- This ensures the **encapsulation** of the data describing each conductor.
- Multiple threads can now act simultaneously on the data for different conductors.

Opera Conductor segmentation



- Some of Opera's conductors are formed from several conductor segments.
- The field due to the conductor is the sum of the fields due to each segment.
- The field due to each segment is independent.
- The fields due to each conductor segment in the model can therefore be calculated concurrently.

OpenMP

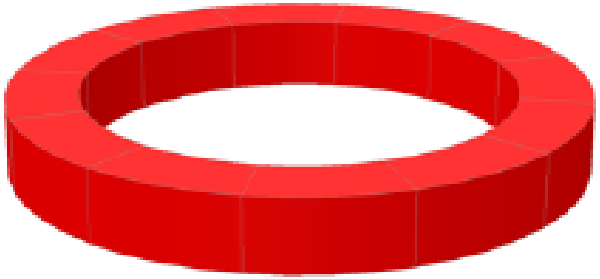
- The restructured library constructs a set of conductor segments. For each of these, the field must be computed.
- This is done by looping over each segment and calculating its field.
- We can share this work between `nthread` threads as follows:

```
! Loop over conductor segments
!$omp parallel do &
!$omp num_threads(nthread)
do i = 1, n
! Compute field
call conductor_segment(i)%compute_field(point, field_tmp)
! Add segment contribution to total field
field(:) = field(:) + field_tmp(:)
end do
!$omp end parallel do
```

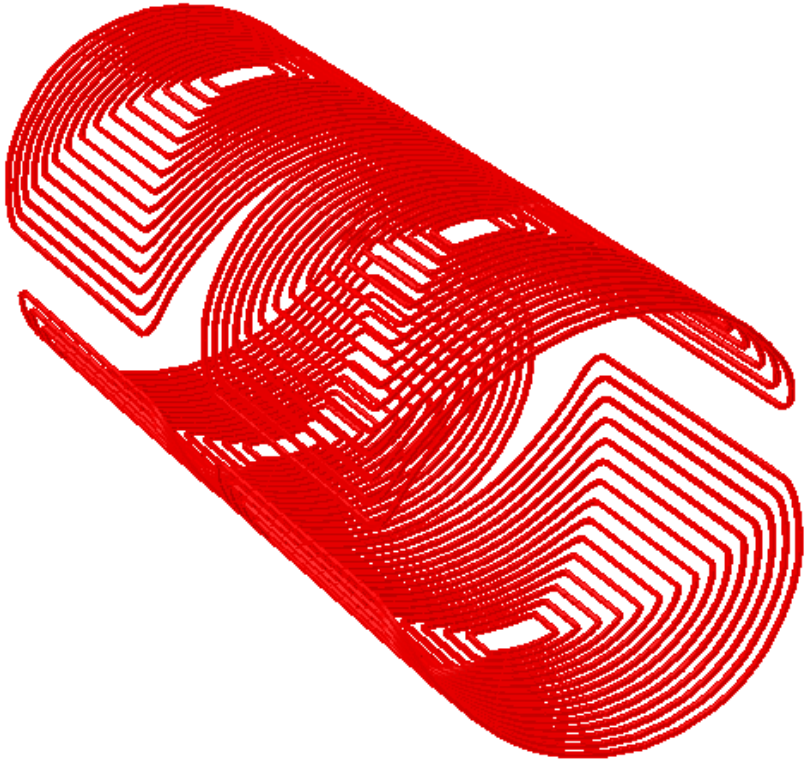
- Care must be taken over the update of shared variables to ensure thread-safety.

Models

- **1 Solenoid – cannot run parallel**

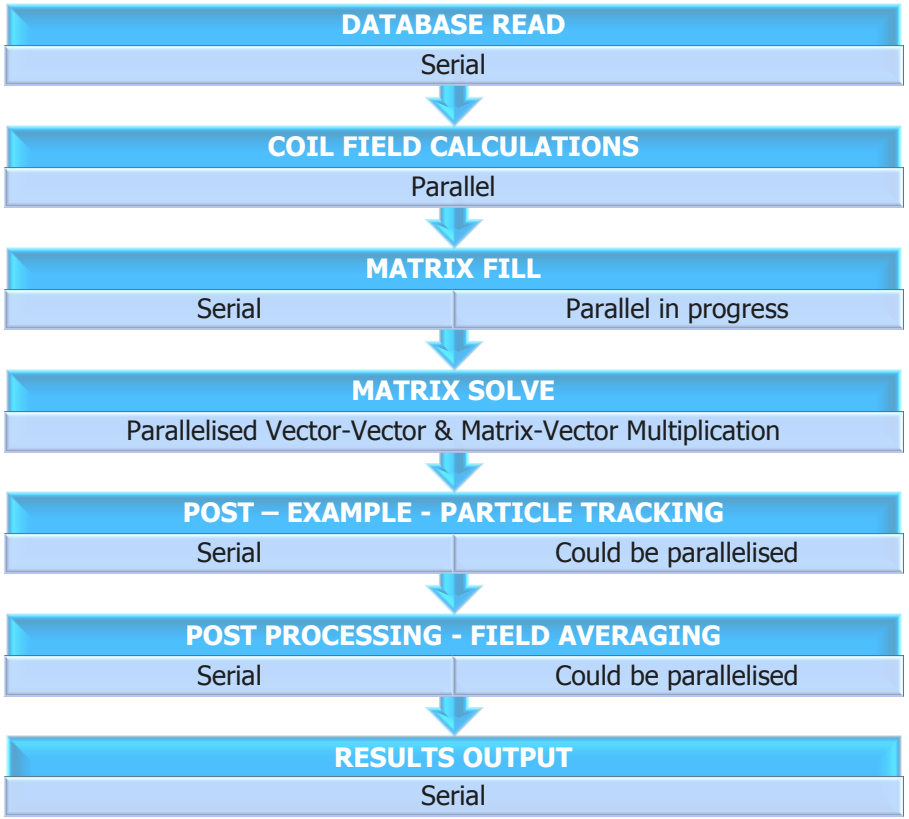


- **"n" B-S Conductors – run parallel**



Opera 16

- In Opera v16 the **solvers only** have been enabled for parallel activity



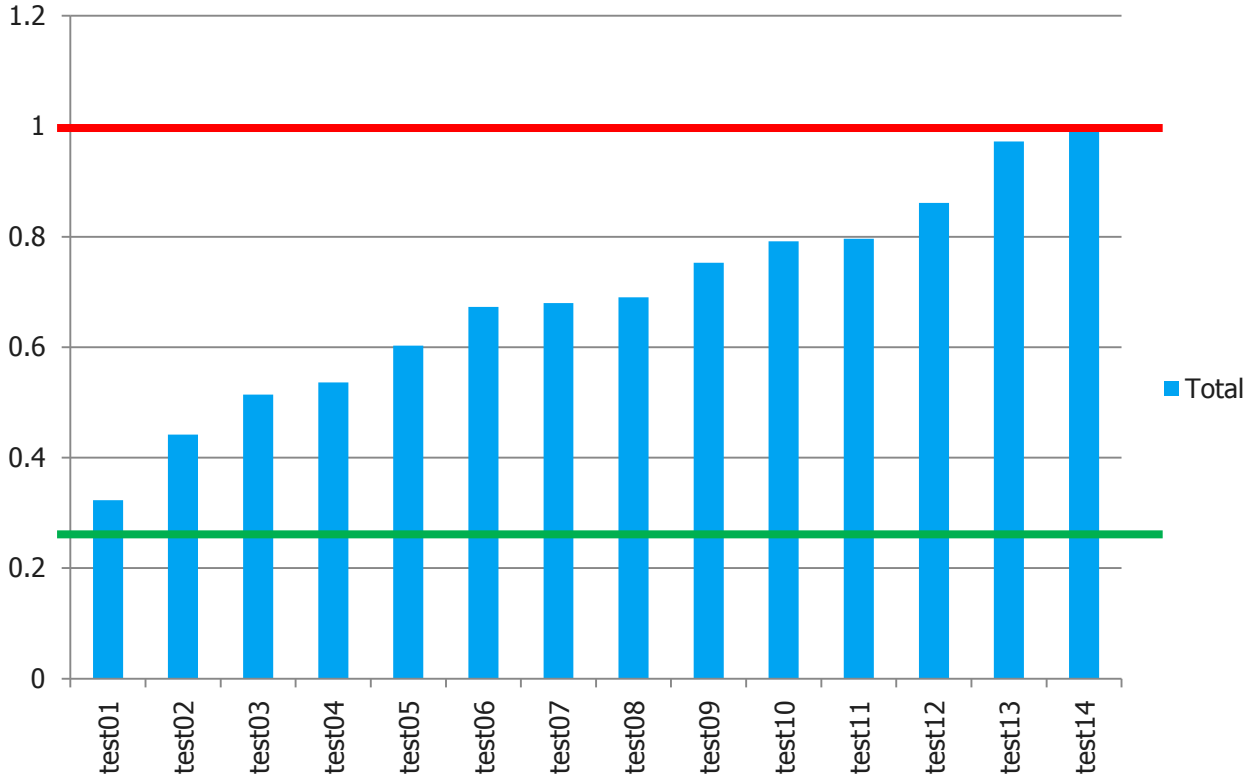
Performance data - Beta

Model Name	Active B-S conductors	Type of conductors	Analysis	Coil field / matrix solve % (4 vs 1)	Fill % (4 vs 1)	Total % (4 vs 1)
Test01	19	Racetrack	TOSCA	25.96%	101.78%	32.32%
Test02	4+12	Racetrack+Bedstead	TOSCA	28.08%	105.22%	44.19%
Test03	4+4	Racetrack+Bedstead	TOSCA	28.72%	147.52%	51.44%
Test04	4	Bedstead	TOSCA	26.77%	160.74%	53.61%
Test05	4+12	Racetrack+Bedstead	TOSCA	28.03%	109.74%	60.29%
Test06	0		Soprano EV	31.00%	93.75%	67.27%
Test07	2	Racetrack	TOSCA	36.56%	100.00%	67.98%
Test08	2	Helical Ends	TOSCA	38.59%	101.42%	69.03%
Test09	0	Circuit	ELEKTRA SS		74.57%	75.27%
Test10	1	Helical Ends	TOSCA	41.72%	98.37%	79.16%
Test11	0		ELEKTRA SS	76.51%	80.49%	79.63%
Test12	0	Circuit	ELEKTRA TR		100.96%	86.11%
Test13	0	Circuit	ELEKTRA TR		97.06%	97.26%
Test14	0	Bedstead	TOSCA		108.86%	99.44%

Disabled before release

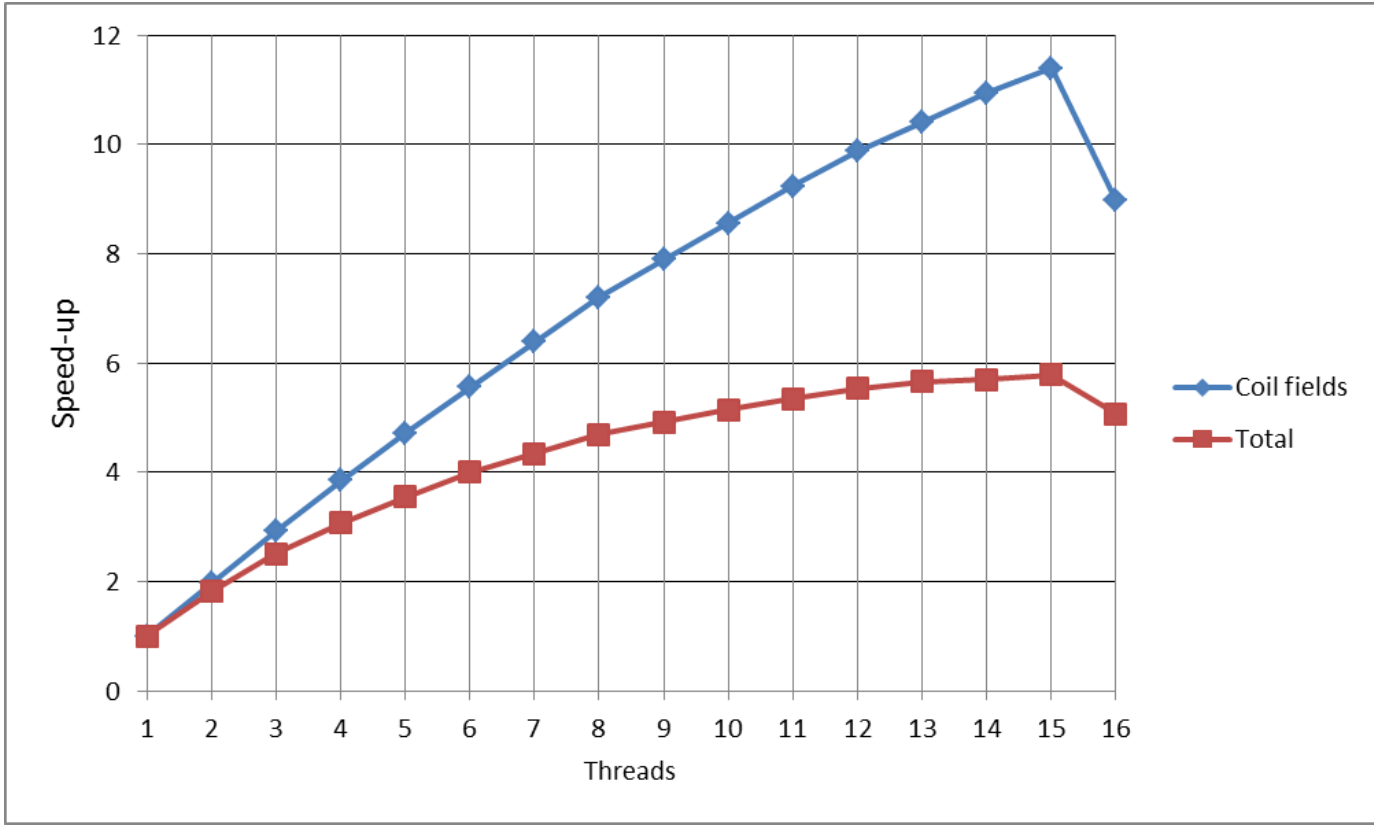
Or, as a graph, 4-way vs 1-way

- **Total solution time for 4-threads vs 1-thread**



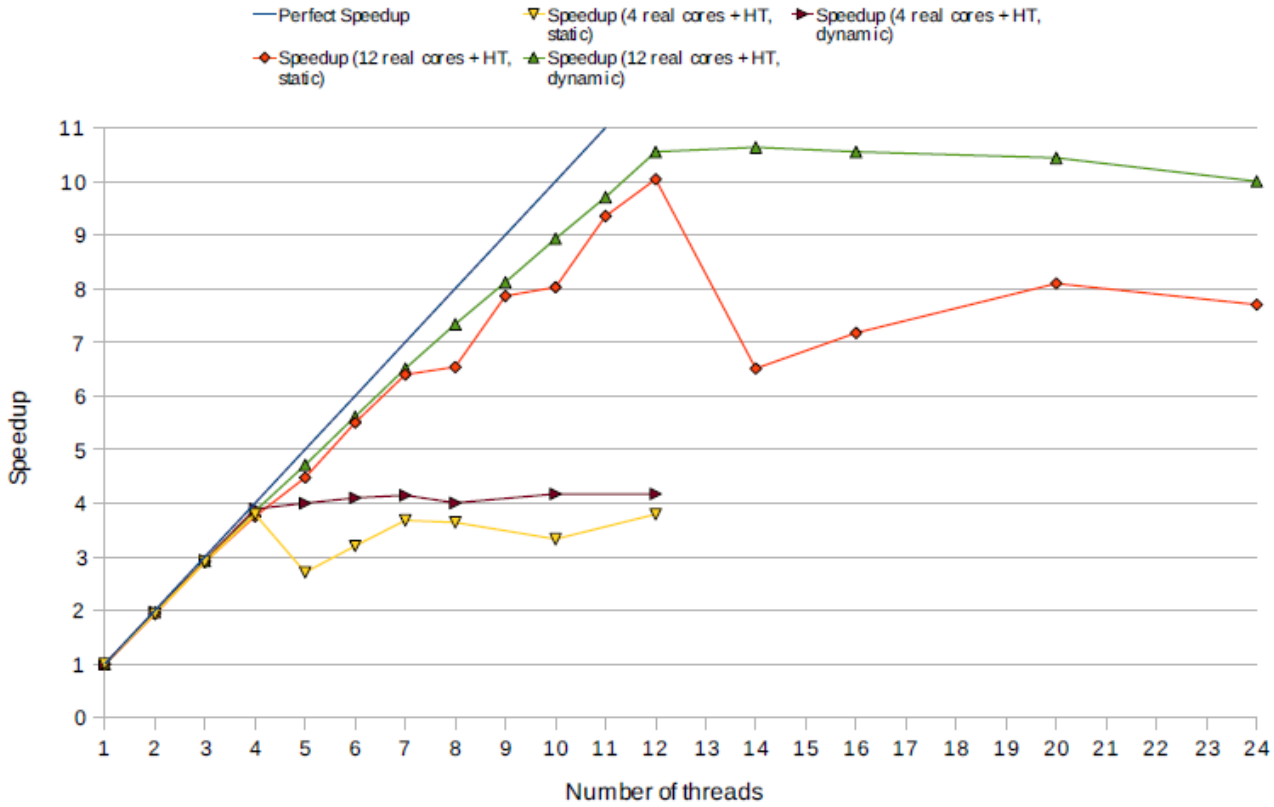
Scaleability

- **Typical testcase with large number of Biot-Savart conductors**
- **Coil Field calculation scaleability is good until we run out of "real" cores**
- **As the coil field calculations are speeded up they account for a smaller proportion of overall solution time**



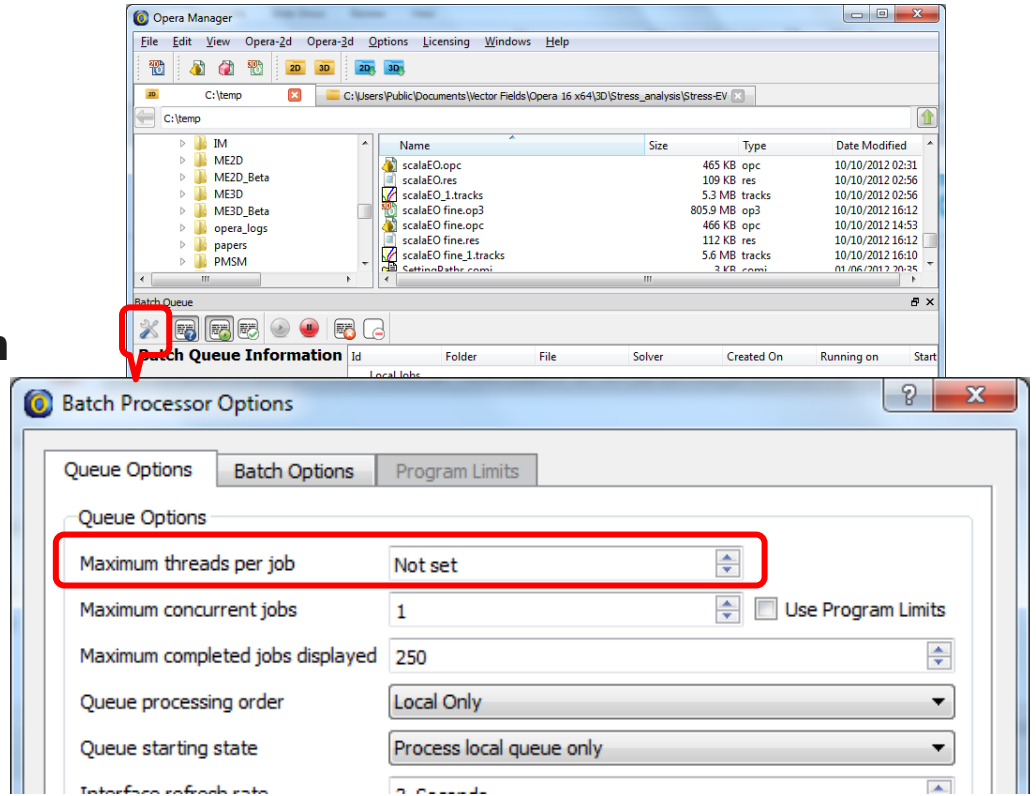
Remember Hyperthreading?

- **Typical effect of hyperthreading**



Opera Manager

- **V16 Opera Manager options…**
  …Maximum threads per job
- **Solver Parallelization**
- **Shared-Memory Implementation**
- **Licensed feature**



Multi-Core Parallel Licensing

- **Multi-Core Parallel is a licensed feature**
- **Sold as Opera-3d Multi-Core Parallel pack**
- **Licensed in usual way – locked or floating**
- **One Pack enables all (applicable) licensed solver types to run up to 4-way parallel**
- **Number of threads to use for each job is set in the Batch Processor Options**
  - Recorded when job submitted
  - Will revert to single-thread if parallel license not available

Multi-Core Multi-Pack Parallel

- **One Multi-Core Pack enables up to 4-way parallel on an individual job**
- **By use of the "Maximum threads per job" multiple Parallel Packs can be spread over a number of active jobs as required**
- **Multiple packs applied to a single job enable 2^{2n} threads:**

Packs	0	1	2	3	4	5
Threads	1	4	16	64	256	1028

Thank You