

Data Sheet PRIMEFLEX for HPC Application Solution for COMSOL Multiphysics in Geophysics & Geomechanics

- Optimised HPC cluster ready for Geophysics modelling with COMSOL Multiphysics
- Expertise in run-time methods available as pre-built packages to assure ROI
- Simplified end-to-end process of acquisition to production

Application Solution for COMSOL

Fujitsu's PRIMEFLEX for HPC Application Solution for COMSOL Multiphysics is a complete HPC cluster system and productive application environment designed for the Geophysics/ Geomechanics market. Through its ability to simulate a wide range of physical behaviour within the same model COMSOL Multiphysics is emerging as a key tool for this industrial sector. And now by combining this with HPC scalability COMSOL users can simulate much finer-detailed models, and significantly increase confidence in these results by systematically applying optimisation methodologies.

Geophysics & Geomechanics is a sector with a particularly large potential to benefit from

simulation. Some of the largest HPC users are already found in this domain. These are now being joined by small and medium businesses, some using HPC for the first time, often working on projects that extend simulation into new areas beyond hydrocarbon extraction.

Simplicity and Expertise

Fujitsu PRIMEFLEX for HPC Application Solutions are architected for optimal price-performance on different workloads, providing an assured basis for higher efficiency and lower risk. But the key advantage in the solution is to expand application usability and access.

Simplicity, delivered through the dedicated Fujitsu HPC Gateway web-based user workplace, broadens the accessibility of tools

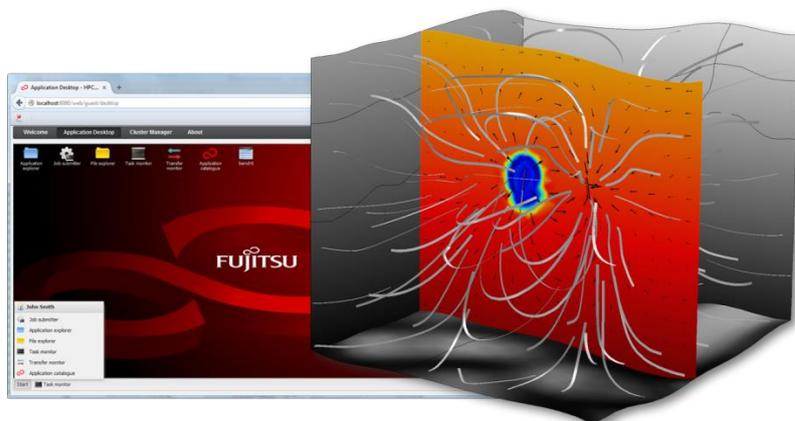
previously reserved for practiced users. Yet the real transformation comes from using proven application methods and leveraging the built-in expertise offered through the solution.

Fujitsu PRIMEFLEX for HPC Application Solutions include pre-built packages to use through the Fujitsu HPC Gateway on the local HPC server, enabling users to take advantage of proven robust and intelligent HPC methods to run more simulation workloads.

Through this powerful combination Fujitsu PRIMEFLEX for HPC Application Solutions help integrate HPC firmly within corporate business processes by delivering reliable and accessible tools for mainstream use.



Pre-configured PRIMEFLEX for HPC Cluster.



Gateway COMSOL interface & result plotter.
[Geothermal simulation image courtesy of COMSOL]



Features and benefits

Main features	Benefits
<p>PRIMEFLEX for HPC - Scalability with COMSOL Multiphysics</p> <ul style="list-style-type: none">■ COMSOL supports hybrid parallelism for the optimal balance between shared and distributed memory execution.■ Clear and structured user interface and the extensive model library allow users to rapidly start preparing HPC models.■ Attractive licensing system allowing optimal use of hardware resources and unlimited access to all available nodes and cores.	<ul style="list-style-type: none">■ Efficient scaling across the range of different physics simulations.■ Increase simulation project size without additional effort or costs.■ The modular structure allows for tailor-made models and applications.
<p>Optimised reference architecture</p> <ul style="list-style-type: none">■ Components selected and architected for optimal price-performance on the COMSOL Multiphysics application.■ Design validated with ISV.■ Preset system patterns for real production workloads: baseline configuration plus balanced step-up units.■ Intel Cluster Ready certification of integrated system in the factory.	<ul style="list-style-type: none">■ Reduced effort in self-configuration and shorter time to decision.■ Risk reduction from proven application performance.■ Simplified adaptation to projected load, no performance bottlenecks.■ No reconfiguration on-site, no delay to entry into service.
<p>Fujitsu HPC Cluster Suite (HCS)</p> <ul style="list-style-type: none">■ Complete system middleware stack including cluster management, batch resource manager and user working environment.■ Fujitsu HCS Basic Edition integrated with main open source batch resource managers.■ Fujitsu HCS Advanced Edition provides cost-optimised bundle with the leading commercial batch system, Altair's PBS Professional.■ Factory installed and preset for customer operations.	<ul style="list-style-type: none">■ Immediately production-ready at system startup, no DIY and post-delivery add-ons.■ Single point of support, faster issue management.■ Integrated monitoring and administration.
<p>Fujitsu HPC Gateway</p> <ul style="list-style-type: none">■ Web user interface giving simpler cluster access from any location and device type.■ Unique and intuitive desktop layout within the browser page, allowing individual arrangement of objects and tools.■ Full set of tools to prepare, run and organise work on the solution cluster.■ Dynamic monitoring of job progress, with graphical presentation of key simulation result metrics and data points.	<ul style="list-style-type: none">■ Full user productivity immediately, no learning costs.■ No Linux knowledge necessary, wider HPC accessibility and larger contribution to ROI.■ Stronger security, lower risk.
<p>Fujitsu Application Catalogue</p> <ul style="list-style-type: none">■ Pre-built packages that encode standardised and best practice application run methods.■ Scope of methods covers Application domain and not just IT level. Current application-specific functions include input file validation, license handling, run-time monitoring, summary reporting.■ Packages downloadable from Fujitsu web site and self-imported, and continuously updated during the cluster lifetime.	<ul style="list-style-type: none">■ Enhanced operational robustness, user productivity and project management.■ Included in HCS price, no service wrap.■ Methods leverage expertise from the widest research from internal & external subject-matter experts.

Topics

COMSOL Multiphysics for Geophysics & Geomechanics simulation

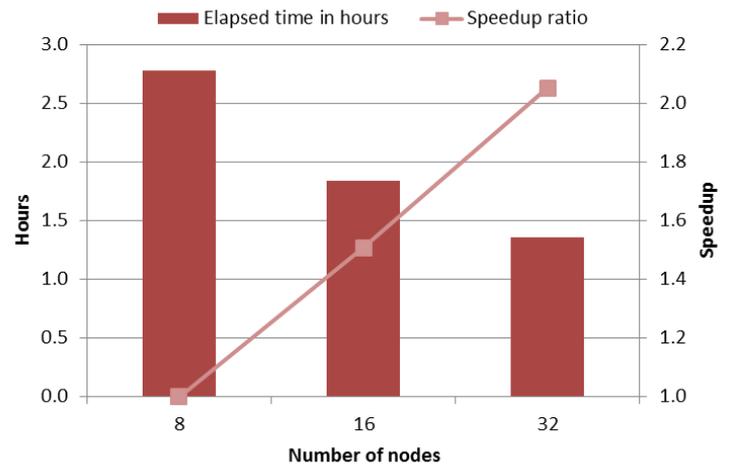
COMSOL Multiphysics offers an extensive platform for the modelling and simulation of physics-based systems. Its advantages are derived from the almost unlimited possibilities for obtaining more realistic predictions of the behaviour of complex coupled systems and processes. The modular structure allows for tailor-made models and applications. An array of physics-based modules augment the core physics interfaces of COMSOL Multiphysics and provide additional interfaces for electrical, mechanical, fluid flow, and chemical applications.

COMSOL without any additional modules already provides interfaces for heat transfer, laminar fluid flow and linear structural mechanics cases. These are sufficient to simulate certain cases for this sector. Exploiting the fully-integrated environment of COMSOL Multiphysics allows for a unified modelling workflow irrespective of the simulation task. For more complete Geophysics & Geomechanics simulations the following components allow to make an integrated analysis of a wide range of different physical conditions:

- **Subsurface Flow Module** for all kinds of subsurface flows, heat transport, poroelastic effects and also chemical reactions.
- **Structural Mechanics Module** for implementing thermal stresses as well as acoustic-structure interaction (fracking, artificial seismicity).
- **Geomechanics Module** combined with Structural Mechanics, for the complex structural subsurface behaviour (drilling, intensive pumping).
- **Pipe Flow Module** can be important for closed-loop shallow geothermal applications as well as for large scale pipeline systems.
- **CFD Module** for computing more complex turbulent flows such as the near region of a geothermal borehole.
- **Heat Transfer Module** when radiation or thermodynamical processes play a role.

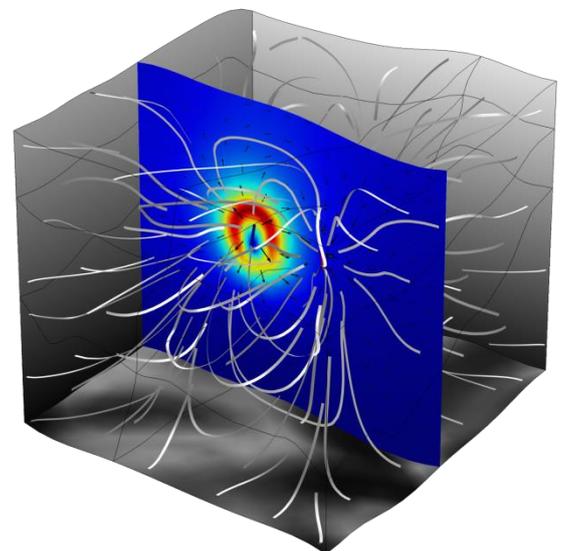
COMSOL Multiphysics combines both distributed and shared memory parallelism to offer highly efficient scaling on Geophysics and Geomechanics models. Moreover, distributed parallelism increases the total memory available for the computation, allowing much larger models to be solved.

A growth area in this sector is geothermal simulation which exploits a range of coupled simulation capabilities within the COMSOL Multiphysics application. A full production-sized (2.47M DOF) time-dependent geothermal model on the Fujitsu PRIMEFLEX for HPC Cluster would complete in under 3 hours on just 8 cluster nodes. If even shorter turnaround is required then increasing to 16 or 32 nodes offer further notable gains due to the efficient parallel solver algorithm in the application. Higher node count also reduces the memory requirement per node to under 20GB.



Applying optimisation to mitigate uncertainties

By its nature, simulation of sub-surface phenomena is subject to some large uncertainties, most obviously the limited knowledge of the precise topology and composition of the medium. An optimisation approach to the analysis provides a means to constrain and potentially reduce these uncertainties. COMSOL Multiphysics includes a multi-purpose **Optimisation Module** that provides state-of-the-art techniques for parameter estimations, backward-simulations, etc. HPC is particularly effective for an optimisation campaign since it provides the capacity to run several simulations concurrently, leading to order-of-magnitude reduction in total throughput time. Without HPC such studies must resort to serialising a sequence of jobs, which means the duration becomes prohibitively long for any meaningful optimisation result.

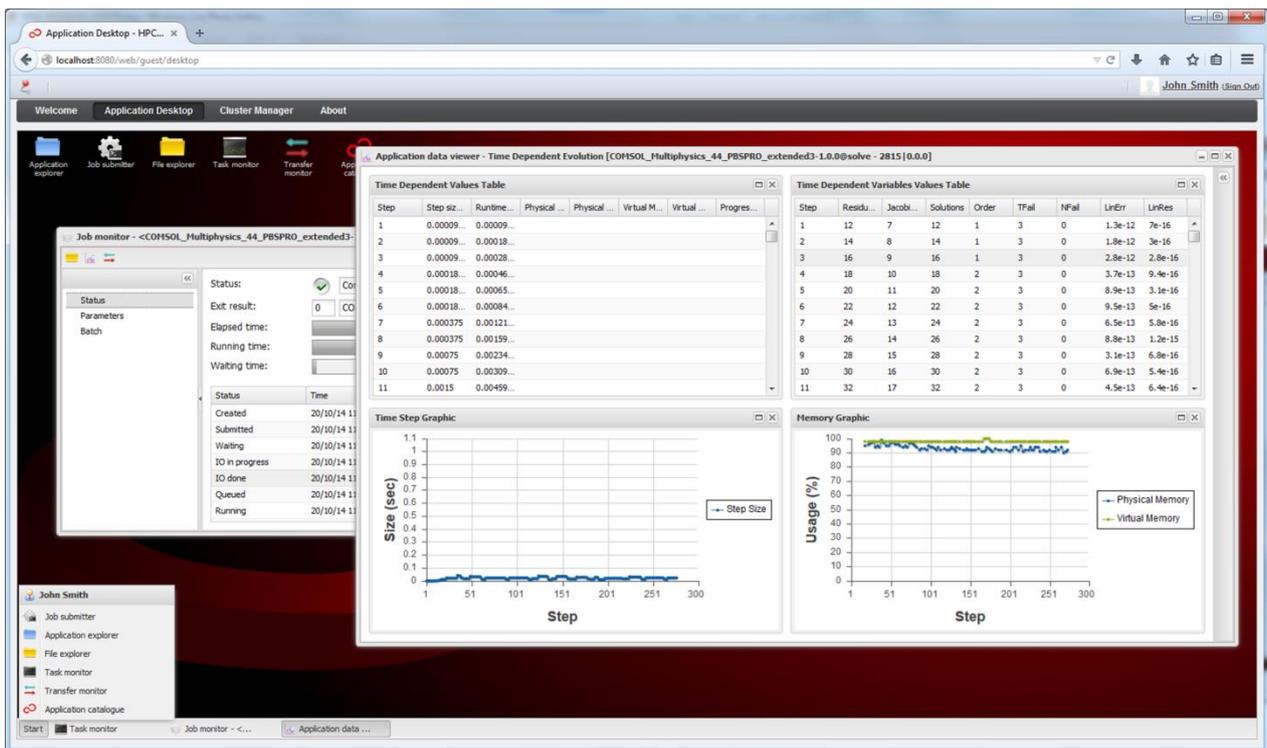


Topics

Simplifying HPC reduces risk and increases potential ROI

An HPC cluster is assembled from a various components – CPU, memory, disk, interconnect, storage, etc. – each with a choice of specification that changes on a regular basis. Optimising this combination for a given objective is costly and requires detailed IT competence to avoid just moving bottlenecks from one place to another within the overall system. COMSOL reference configurations are based on continuously-updated measurements of application performance with realistic models, reducing the time and cost of acquisition, and lowering overall risk.

Other sources of risk include operational performance and user productivity. Reference patterns for different workloads allow better initial matching to project needs. Aggregate user productivity combines two factors: individual efficiency, and expanding HPC to more end-users. In most HPC systems user productivity is eroded by time lost in dealing with IT, rather than preparing and analysing the results of simulation. The Fujitsu HPC Gateway providing the Fujitsu Application Solutions eliminates completely these issues through an intuitive integrated workplace. Simplifying HPC can have a transformative impact for project/group leaders. Such democratisation of HPC means this capability becomes accessible and usable for more engineers, designers, domain specialists and technicians. Businesses can then apply this power to expand exploration of a products design space and to increase performance, quality, reliability, and ultimately innovation.



Expertise in application methods for COMSOL Multiphysics

Sustaining productive use of HPC across more projects and workloads requires a means to effectively capture and propagate expertise in application methods. The Fujitsu HPC Gateway user workplace within the Fujitsu HPC Cluster Suite (HCS) includes a workflow engine that automates programmed methods, dispatching jobs on the cluster and implicitly moving data throughout the complete process. With the Fujitsu HPC Gateway in HCS Advanced Edition customers can develop their own workflows to capture and scale processes that are the unique competence of their organisation.

Fujitsu offers an Application Catalogue of methods encoded as pre-built packages for download and import into the local Fujitsu HPC Gateway installation. Integrating expertise in automated methods enables new and existing HPC users to leverage knowledge on a scalable basis. The Fujitsu Application Catalogue offers robust processes for running COMSOL Multiphysics, including dynamic visual monitors to track results in progress.

Technical Specifications

Baseline configuration		Description
Compute nodes – COMSOL Multiphysics		4x FUJITSU Server PRIMERGY CX250 S2 in one CX400 housing
For each node:		
	CPU	2x Intel® Xeon® Processor E5-2680v2 10C/20T 2.80 GHz 25 MB Where higher performance is needed COMSOL Multiphysics can also take full advantage of the fastest processor in the range: Intel® Xeon® Processor E5-2690 V2 10C/20T 3.00 GHz
	Memory	8x 8GB DDR3-1866 R ECC memory For computations involving more structural mechanics simulation: 16x 8GB DDR3-1866 R ECC memory
	Local disk	1x HD SATA 6G 250GB 7.2K HOT PL 2.5" BC
Head node		1x FUJITSU Server PRIMERGY RX300 S8
	CPU	2x Intel® Xeon® Processor E5-2630v2 6C/12T 2.60GHz 15MB
	Memory	8x 4GB DDR3-1600 R ECC
	Local disk	8x SATA 6G 1TB 7.2K HOT PL 2.5" with RAID 5/6 setup 2x SAS 6G 300GB 10K HOT PL 2.5" with RAID 1 setup
Fast interconnect	Parallel communication, Parallel IO	InfiniBand Intel QDR switch 36 port 40Gb/s 1x IB HCA 40Gb 1 port QDR per compute node
Standard interconnect	Management, NFS	Brocade ICX 6430-24, 24x 1GbE RJ45
External storage		FUJITSU Storage ETERNUS offers a range of suitable options

Notes:

The selection of optimal CPU, as well as other components, is continually reviewed by Fujitsu. Extensive benchmarking is done both with a range of models representative of real production, including full physics, as well as standard performance test cases that explore scalability and the detailed interplay to balance the various cluster components.

Software environment

Cluster software stack		FUJITSU Software HPC Cluster Suite (HCS) V2.2 Advanced Edition
Cluster user environment		Fujitsu HPC Gateway included in HCS
Batch resource manager		Altair PBS Professional
Operating system	Head node	Red Hat Enterprise Linux
	Compute node	Red Hat Enterprise Linux HPC
Application workload management		
	Cluster	COMSOL Multiphysics
	Client	COMSOL Desktop
	Automated methods	Pre-built packages for running COMSOL Multiphysics are downloadable from the Fujitsu Application Catalogue

Workload solution

Specific HPC job counts are dependent on the organisation, but a solution can be patterned for certain types of workload based on threshold requirements for the given scenario. This can be set by parameters including a target model size, the engineering team headcount, or the optimisation throughput needed to address the simulation uncertainties.

Scenario	Baseline CPU	Node count	Total cores
<ul style="list-style-type: none"> ▪ Stretch model: highest resolution single job, finest mesh, largest DOF count ▪ Optimisation becomes systematic using large-scale concurrency ▪ Expanded HPC access to wider team ▪ Multiple concurrent projects ▪ Increased multiphysics 	Intel® Xeon® Processor E5-2690 V2 10C/20T 3.00 GHz	16	320

Related Products and Services

FUJITSU Server PRIMERGY

Fujitsu PRIMERGY servers provide powerful and flexible data centre solutions for companies of all sizes, across all industries and for any type of workload. This includes tower servers, rack-mount servers, scalable blade systems, as well as density-optimized scale-out servers. They convince by business proven quality with a wide range of innovations, highest efficiency cutting operational cost and complexity, and provide more agility in daily operations in order to turn IT faster into a business advantage.

Please find further information at www.fujitsu.com/fts/primergy

FUJITSU Workstation CELSIUS

Available in a mobile, desktop or rack form factor, CELSIUS workstations are configurable for your organization's precise needs. A broad choice of processors, ultra high-end professional graphics cards, compute cards and hard drives increase application efficiency. On top, Fujitsu's whisper quiet desktop workstations help you maximize productivity by contributing to a quieter working environment thanks to low noise emissions between 18 to 23 dB(A).

Please find further information at www.fujitsu.com/fts/celsius

Fujitsu OPTIMIZATION Services

Does your infrastructure fulfil the requirements of your IT operations? An efficiency analysis of your data centre can be conducted to clearly identify all the factors that affect the security, reliability and energy efficiency of your IT operations so that qualified recommendations for optimization can be made. In addition this service also takes the efficiency of the recommendations into account to ensure maximum cost-effectiveness for your operations.

Please find further information at www.fujitsu.com/fts/services/business/it-consulting/

Fujitsu Financial Services

Fujitsu Financial Services combines financial and commercial expertise to ensure that your IT environment financing strategy – including hardware, software and services - is underpinned by flexible payment terms that align to your business and financial objectives. Our services cover the complete lifecycle starting with financial planning, technology replacement, acquisition, financial management and retiring of assets of your IT environment - allowing you to concentrate on your core business.

Please find further information at www.fujitsu.com/fts/finance

More information

Fujitsu OPTIMIZATION Services

In addition to PRIMEFLEX for HPC Application Solutions, Fujitsu provides a range of platform solutions. They combine reliable Fujitsu products with the best in services, know-how and worldwide partnerships.

Fujitsu Portfolio

Build on industry standards, Fujitsu offers a full portfolio of IT hardware and software products, services, solutions and cloud offering, ranging from clients to datacenter solutions and includes the broad stack of Business Solutions, as well as the full stack of Cloud offering. This allows customers to leverage from alternative sourcing and delivery models to increase their business agility and to improve their IT operation's reliability.

Computing products

www.fujitsu.com/global/services/computing/

Software

www.fujitsu.com/software/

More information

Learn more about Fujitsu PRIMEFLEX for HPC Application Solutions, please contact your Fujitsu sales representative, Fujitsu business partner, or visit our website.
<http://www.fujitsu.com/fts/hpc>

Fujitsu green policy innovation

Fujitsu Green Policy Innovation is our worldwide project for reducing burdens on the environment. Using our global know-how, we aim to contribute to the creation of a sustainable environment for future generations through IT. Please find further information at www.fujitsu.com/global/about/environment/



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