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REPORT OF A WORKSHOP ON MULTICORE COMPUTING

IET Savoy Place June 26th 2009

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EXECUTIVE SUMMARY

A Workshop addressing the many economic and technical issues raised by Multicore Processors (MCPs) was held at the IET, Savoy Place, London on June 26th 2009, led by Concertant LLP and The 451 Group, on behalf of the Technology Strategy Board (TSB) and its Knowledge Transfer Networks (KTNs). The forty-odd delegates were senior representatives of major hardware and software vendors, a cross-section of industrial and commercial companies, academia, the TSB, the KTNs and the UK Research Councils. The objective of the meeting was to identify how action by industry, government, academia and other stakeholders could assist in the take-up of MCP technologies with maximum short and long-term benefit to the UK economy.

The meeting concluded that the deployment and exploitation of MCPs, which will change computing technologies and where the short and medium term economic cost will run to many billions of pounds, must be supported if the UK is to deliver the goals of Digital Britain.

The meeting recognised a lack of preparedness at all levels, in particular among senior management, of the commercial impact of MCPs. In order to combat this it recommended a strategy that could include the creation of a Multicore Institute to exploit existing UK skills in MCP technologies, to act as a centre of excellence, co-ordination of knowledge transfer and best practice. Such a body might be financed by a mixture of Government and industrial sources together with income from commercial services. The resulting resource would be leveraged to provide greater value to UK industry. However, additional funding would be required to support the deployment and exploitation of multicore devices sufficiently.

The Multicore Institute, in collaboration with other stakeholders would have responsibility for:

- ***Awareness Creation:*** to ensure that business executives understand the impact of multicore devices. These activities should include estimation of quantities such as improvement in efficiency and capability arising from the deployment of multicore-based systems.

- ***Training:*** to enhance the UK skills base. This is needed because most developers are neither multicore nor parallel programming experts.

- ***Programming and Pilot Projects:*** Expert assistance to support inexperienced users in the programming of multicore systems. This should be complemented by pilot projects used as both training exercises and case studies. As part of these activities one or more repositories of best practice might be established with appropriate training resources.

- ***Creation of Multicore Ecosystems:*** A source of best practice and a forum for discussion of multicore issues. The UK has many multicore skills, but the community is fragmented and needs a focal point.

Any such putative institute should be independent from, but working closely with, a number of existing bodies including appropriate KTNs and other stakeholders, industry and academia.

The meeting agreed that a number of longer-term actions were necessary. These include:

- **Education**: Many of those recruiting in industry find that current IT education fails to provide the skills that they require. Programming skills should start being taught at schools. Graduate and undergraduate teaching should focus more on computer science and less on IT. The skills shortage is serious in advanced areas such as parallel programming.

- **Tools, Languages and Standards**: The UK should increase investment, and international cooperation, in areas related to the deployment and exploitation of multicore devices.

- **Hardware isolation**: Applications must be built so that they can take advantage of new features without regular redesigns as multicore processors evolve and become more complex with progressively higher core counts.

These activities would be separate activities from any MCI. The meeting felt that failure to address these issues would be to the economic detriment of the UK and would result in further erosion of the scientific capability of the UK in comparison to its industrial, commercial, academic competitors and its global competitiveness.

1. INTRODUCTION AND PURPOSE OF THE WORKSHOP

1.1. Background

The objective of the workshop was to identify those areas where action by industry, government and academia could benefit the short, medium and long-term interests of the UK economy. More specifically, the goal was to identify where investment by the TSB and other stakeholders could improve the competitiveness of UK plc in the development and exploitation of multicore processors.

A position paper was sent out in advance to workshop participants in order to focus and stimulate the discussion. The position paper for the meeting is appended to this report. Participants at the meeting from the UK and abroad included senior executives at CTO or equivalent level from industry and commerce, major software and hardware providers and academia together with other stakeholders including the TSB, EPSRC and the TSB Knowledge Transfer Networks (KTNs). Industrial and commercial participants were actively involved in the business development and marketing activities of their organisations.

The meeting was attended by representatives of industry, academia, UK Technology Strategy Board, TSB's Knowledge Transfer Networks and the UK Research Councils. In order to facilitate discussion, the meeting was held under The Chatham House Rule.[1]

Multicore technology[2] is important to the economy because it applies to all areas of computing areas from embedded systems through to supercomputers. This technology will have implications for low-level hardware and software as well as for high-level programs. The inefficiencies that could arise from failing to use this technology properly could have a substantial economic impact. Multicore technology is so important because it has become the dominant processor architecture in a short space of time and is set to continue changing computing over the coming decades.

Multicore devices are becoming all-pervasive, deployed in embedded systems in washing machines and cars, mobile telephones, communications networks including the Internet, as well as in high-performance systems running applications in sectors including pharmaceutical, petroleum, aerospace, finance, engineering and research. As a result multicore technology impacts significantly on the delivery and exploitation of Digital Britain[3].

The market for embedded processors alone is of far larger economic importance than is generally realised. Approximately 98% of all processors are manufactured for the embedded market[4]. A laptop, for example, has only one Intel processor, but four embedded processors from ARM. Four billion ARM processors were shipped in 2008[5]. Many modern embedded processors are multicore, particularly in the strategically important leading-edge industries. To date there are 22 and 25 billion embedded processors deployed globally, with a 2004 market value for systems and related services of approximately £1.15 trillion with growth of about 17% per annum. Embedded hardware accounts for between 20 and 40% of the final price of products shipped with an estimated component value of $88 billion per annum at 2006 prices[6]. The market already includes many multicore processors and going forward it will become increasingly dominated by them.

The efficient deployment of multicore devices requires a shift in programming models. To take full advantage of the computing power offered by a single multicore device, applications will have to be redesigned to exploit several or all of the cores within that device simultaneously. Those applications not redesigned may well run more slowly on future generations of processor than they do on current devices! Techniques such as, virtualisation[7] of the underlying hardware, or advanced compiler technologies will be necessary to ensure that applications do not need to be redesigned and optimised for each new generation of device. This will apply equally to third party and in-house applications.

Initial indications based upon data from Concertant, the Office of National Statistics and HM Treasury[8] lead to an estimate that UK industry will have to spend about £80billion on implementing multicore-based systems over the period 2008 to 2013, and that without appropriate investment to address the multicore programming issue that amount will continue to increase. An appropriate investment at this stage could help to reduce this massive outlay and would increase efficiency and hence productiveness (see below).Without the investment on the other hand competitiveness will drop behind competition, with resultant likely economic impact.

Multicore is and will remain at the heart of new advances in economically important industries such as finance, which contributes approximately 9% to UK GDP. Without local expertise to develop and deploy applications with the highest levels of performance, the UK will not be able to continue to benefit from this revolution.

This lack of expertise in the techniques needed to program multicore devices effectively will be a barrier to the realisation of the goals of Digital Britain. For homogeneous multicore devices, these techniques have become known as “parallel processing” where several processors (or cores) are deployed on the same application. In the late 1980 and 1990s the UK had a world-wide lead in this area. Much of the expertise developed remains and needs to be widely disseminated across a new generation of programmers

To develop and consolidate its competitive position relative to partners in Europe, the UK needs to invest in the promotion of skills and training in the deployment of multicore devices. France and Germany already have national activities in this area. In the US and Japan there is activity at a wide range of levels from industry to academia with a national commitment from the new Administration. The UK currently lacks comparable activities in this area to those of its competitors.

The UK does however have comparable intellectual capital having invested heavily[9] in relevant technologies, such as parallel processing, over nearly two decades. This investment was identified by the meeting as a resource which could, and should, be exploited for the national benefit.

1.2. Electronics KTN Orientation Workshop

In April the Electronics KTN held a workshop on Multicore Computing to ascertain the impact that its members felt that the technology would have on productivity and performance. It was identified that tools existed to develop software for multicore systems, but in general they were difficult to use, were not user friendly and were not widely known.

The meeting identified that the UK has relevant expertise upon which it could build, particularly from the embedded and high-performance computing sectors. That meeting felt that a concerted programme of technology transfer, perhaps coupled to a “Multicore Institute”, a National Centre of Excellence, that could identify needs, assemble expertise and provide a mechanism to facilitate new collaboration, would be of particular value to the community. The specific activities required are set out later in this document.

The meeting was particularly clear that issues related to multicore technology are not limited to high-performance computing. They apply to most application sectors of the software industry. Multicore is a cross-cutting technology. The embedded sector was emphasised this particularly strongly.

2. SUMMARY OF THE WORKSHOP

The following is a summary of the major points raised during the discussion at the workshop held on June 26th.

2.1. General

MCPs are an enabling technology that cut across many areas including defence, finance, communications, control, graphics, networking, geology and petroleum, medicine, entertainment and many others.

Coordination between the TSB and EPSRC and other stakeholders including industry in support of a national multicore "research" focus is desirable.

The move to MCP-based architectures is inevitable and is the declared route of all major processor manufacturers and designers. It is essential that the UK has a coordinated voice in the US-based Multicore Association. At the same time the UK must create its own such association in order to create an ecosystem to enhance the UK's capability in the area. This should in turn co-ordinate with EU activities such as ARTEMIS.

The "desktop", embedded and HPC sectors are substantially different, but share many common issues. All can benefit from each other's experiences. As an example, HPC experience gained from programming systems with high core counts can benefit other sectors.

The UK has a long tradition and substantial expertise in parallel processing[10]. This expertise must be consolidated and disseminated through training and the creation of awareness at the management level in order to make full use of this intellectual capital.

Multicore technology will be a major enabler of growth in new and emerging industrial areas such as Biotech, Finance, Information, Entertainment and Communications. This reinforces the importance of the need for:

- Coordination between stakeholders particularly TSB and ESPRC;
- A coordinated UK-based multicore association.
- A UK voice in the US-based Multicore Association;
- Cross-fertilisation across the embedded, desktop and HPC sectors;
- Training and awareness creation involving both managers and programmers.

2.2. Industry issues

A strong opinion was expressed at the meeting that any measures, adopted to promote the exploitation of multicore, must identify the needs of industry and develop tactics and strategy to ensure that the UK benefits competitively from the clear opportunities. The dangers of doing nothing were stressed, particularly given developments in the USA and Japan and the emergence of significant software capabilities in Eastern Europe and the BRICs countries.

Members of the workshop reported that there was a reticence on the part of industry to adopt multicore processors, because they were seen as new and difficult to use. However, of those responding the Concertant Annual Multicore Survey 2008, 75% of those that had adopted multicore technologies reported that they had seen an improvement in ease of use/productivity/performance[11]. This does not however imply that they are using them in either the most efficient or productive manner. Nor (see below) does it mean that the experience gained with current generations of multicores will transfer well to the next generation

As part of the promotion of multicore technology to industry at large, there need to be effective metrics to demonstrate the return on investment (ROI) from its use. These metrics should address issues such as reduced design and implementation time through the use of effective tools as well as the lower-power consumption of multicore devices, with the impact on ROI and the environment that goes with their deployment The collection of data to support arguments in favour of multicore technology is not expected to be an easy task.

The group attending the workshop in June was well aware of the benefits of multicore technology and related technical issues. The major issue is to address the vast majority of developers who do not have that level of awareness and expertise. There needs to be a concerted campaign of awareness creation to demonstrate how the potential of multicore can be realised through the use of appropriate tools and the adherence to established best practice.

Government intervention is needed to initiate multicore support activities which, with the involvement of industry, could develop a level of sustainability. The Multicore Institute discussed above could be an effective model to follow involving the major industrial stakeholders, the TSB and the Research Councils.

2.3. Hardware issues

The mainstream processor market has already reached six cores per processor. Systems comprising several such processors which share memory are commonplace. Clusters where many such systems are connected by a fast network are in wide use. These may contain tens or hundreds of cores. In graphics processing units (GPUs) and in signal processing systems there are already hundreds of cores in a processor.

Next generation processors will have core counts similar to those of clusters. However, they will have much more effective inter-core communication in terms of bandwidth and communication delays. It seems likely that devices containing many cores will be fault-tolerant, that is they will be able to reconfigure themselves in the event of the failure of individual cores.

The number of cores on a single die is set to grow[12] rapidly for the foreseeable future. Mean time between core failures on a single device will decrease sharply[13] with resultant impact on performance and reliability. This implies that such devices will have varying performance over their lifetime. This will have implications at the system design level where appropriate tools will be needed to address this feature. Issues related to scalability, memory models, thermal management and chip physics will become even more important than they are today.

Performance, power and programmability will become progressively more important. Tools will be needed to support the optimisation of systems with respect to these three issues. For example, FPGAs can deliver very high performance at low power, but are extremely difficult to program.

2.4. System software issues

Users and developers prefer a level of abstraction which isolates them from the underlying architecture. They need it to be hidden behind good tools. Both this workshop and its precursor, highlighted the need for tools for “programming” as being the key to opening the multicore paradigm to the wider programmer base. This was especially true for the more complex GPU/FPGA/accelerator technologies where the currently available tools are in their infancy. How to translate hundreds of cores (by 2017 to 2020) into application performance through the use of appropriate programming models was highlighted at the workshop as being at the heart of the problem.

Processor clock speeds are falling. Consequently applications will run more slowly unless they can properly exploit multiple cores.

Functional and data parallel languages (including Excel, SQL, F# and Haskell) and emerging languages such as CUDA, OpenCL, Ct or PGAS are needed to exploit effectively the capabilities of current and future multicore processors.

Process-oriented (or very high-level) programming tools can help to insulate the programmer from hardware issues whilst still retaining a good level of performance. Such tools need to be developed and to run on a range of platforms.

Programming embedded systems had generally been a custom activity with code being tailored to the characteristics of individual processors or processor families and to the specifics of the target system. However, the increasing complexity of systems and of the individual components which comprise them, means that new tools are needed to enable productive and efficient programming. Training has an important role to play in the deployment and use of new generations of tools.

The effective programming of multicore systems embracing embedded, desktop and supercomputer systems will require skills in parallel programming. Parallel programming is very hard. In particular, debugging parallel codes is extremely demanding. The UK has significant expertise in this area, accumulated over the last three decades. UK tool companies such as Allinea, Codeplay and Critical Blue have world-leading products. This expertise and a nascent software industry represent a significant opportunity to develop a UK capability with substantial economic potential.

There is a clear need to work internationally on the development of software standards including languages, libraries and APIs to aid portability and hide complexity. It is not in the interest of UK industry to stand back from these standardisation activities and then have standards imposed. Rather the UK, should engage in these activities in a coordinated way to support its software tool industry. Both companies and academia have an important role to play in this.

Short, medium and long-term strategies need to be addressed with respect to tools for the programming of multicore devices. In the short term effective use needs to be made of existing tools and this is a matter of training programmers in the use of these tools. In the medium and long-term resources need to be available in order to develop the next generation of tools that will allow the effective and rapid deployment of future generations of multicore devices. This represents an opportunity for the UK to use its expertise base and lead in the development of these next generation tools. Technology transfer from the strong UK academic base will be important in training in the use of tools, in the establishment of best practice and in collaborations leading to the development of new tools and standards.

2.5. Application issues

Legacy applications will need to be rewritten to benefit from multicore technologies. New parallel algorithms will need to be found in some cases where the legacy code is fundamentally serial.

Software vendors will need to address multicore software licensing issues. This applies both to devices with conventional microprocessor cores and to GPUs and will become more pressing as core counts rise. The workshop felt that such licensing issues were a barrier to the effective use of multicore devices and needed to be resolved urgently.

In porting legacy applications to multicore platforms significant attempts should be made to re-use existing code. Indeed software re-use may be a more appropriate term than application porting. The development of repositories with examples of best practice and exemplar codes could help programmers and users alike to exploit multicore devices.

The development of applications targeting multicore processors is in general hampered by a lack of technical awareness amongst programmers. This is compounded by a lack of understanding at the management level of the issues that must be addressed. There is a clear need for both awareness creation and training for management as well as technical staff.

2.6. General Software Issues

Given likely rapid changes in hardware architecture and core counts, the preservation of software investment will become difficult because target devices will change materially.

Without tools and new methods to insulate the programmer from the target hardware, the economic cost of redesigning software for each generation of hardware will become very high. New technologies such as virtualisation which can abstract the application from the underlying system will need to be developed. This is an important long-term activity which nevertheless needs to be considered now.

3. CONCLUSIONS AND RECOMMENDATIONS

This section presents the conclusions of the workshop.

3.1. Overview

The Meeting made recommendations for both short-tem and for longer-term actions. These are set out below

The meeting was of the opinion that many of the short-term roles would be best handled through a

- Multicore Institute which would work in conjunction with other structures such as the KTNs. This re-iterated the need for such a body expressed by the E-KTN at its April Workshop. It was agreed that the Multicore Institute working together with other stakeholders, including EPSRC, other research councils and government departments, would also be able to address the longer-term issues effectively. The nature of the longer-term issues is such that they might benefit from a competitive call for projects in the relevant areas. Any institute should be independent from, but working closely with, a number of existing organisations and stakeholders. The constitution, scope and duties of the institute was outside the scope of this workshop and would have to be decided separately.

3.2. Short-Term

The following short-term actions were identified as being necessary:

- Awareness Creation: Awareness creation in industry was identified as a major target area for action. Many senior managers did not understand the impact that the migration from single-core devices to ones with multiple cores, either homogeneous or heterogeneous, would have both on their commercial activities and on the way that their IT capability was deployed.

These activities might include cost-benefit analyses based upon estimation of quantities such as improvement in efficiency and capability arising from the deployment of multicore-based systems and the overall costs of deployment, .vs. costs of non-deployment

It was proposed at the workshop that a series of seminars and web events be held in order to raise awareness of the impact and the benefits of the technologies among management, particularly at the highest levels. These could be operated in conjunction with other government initiatives and with bodies such as the IOD, BCS and IET.

- Training: Multicore technology requires the use of parallel programming. In parallel processing a problem is broken down into a series of interacting tasks where each task runs on its own core. Most developers are neither multicore nor parallel programming experts. Based on data from European training centres HPC substantially fewer than 1% of programmers are “parallel-literate”[14], perhaps fewer still have commercial or industrial experience using parallel technologies. This has arisen in part as a result of the lack of attention paid to parallel programming at universities and other academic centres.

In the short term, the lack of relevant expertise can be partially addressed by a series of one-day to one-week training courses which can explain the basics of parallel application design and multicore programming. Various courses run by centres of excellence would also address how to use today's software development tools to get the best from multicore systems. This measure however will not completely address the problem and attention has to be given to improving training for computer programmers to ensure that they have the necessary relevant skills.

- Application Porting and Pilot Projects: Expert assistance is required to support inexperienced users programming multicore devices. Pilot projects can be used both as training exercises and case studies to educate others. The use of case studies from the academic environment is of potential benefit here.

- Creation of Multicore Ecosystems: While the UK has a base of multicore skills, the community is fragmented and there is neither a source of best practice nor a forum for discussion.

3.3. Long Term

The Meeting felt that in the medium and longer term there are many issues that need addressing. These are principally:

- Education: To complement the short-term tactical training proposed above, it was suggested that educational standards need to be raised. Programming should be taught at schools, while graduate and undergraduate teaching should focus more on computer science and programming and less on IT.

- Tools, Languages and Standards: Today's tools will not be able to cope effectively with the processors of the next decade. The UK should increase investment, and international cooperation, in this area with the aim of establishing a base of tool expertise and capability and exploiting the significant intellectual capital built up in academe. As a word of caution, the difficulty of programming parallel systems should not be underestimated.

- Hardware Isolation: As multicore processors evolve and become more complex, applications must be built that can take advantage of new features without regular redesigns. A virtualisation layer (see Footnote 7) or other approaches will be required to isolate applications from changing multicore architectures. While this is a longer-term project, activity in this and related areas needs to begin soon in order to take full advantage of the undoubted benefits of the multicore revolution.

3.4. Support for Multicore Deployment in the UK

Multicore Institute: An institute should be founded to provide a focal point for multicore training, application porting and pilot projects. This would be financed by a mixture of Government funding, industry subscriptions and income from commercial services. Funding would thus be leveraged to provide a much higher value to UK industry. It s role would be in conjunction with the KTNs and others, of whom it would stand independent.

Knowledge Transfer Network: The KTNs and other bodies have an active part to play in conjunction with any Multicore Institute in at least parts of the short-term activities proposed above, but additional funding would be required to support sufficiently the deployment and exploitation of multicore devices.

Recommendations

The Meeting strongly recommended the above areas as being in need of urgent support of Government, Industry, Academia and other stakeholders. Whilst recognising that not everything could be achieved immediately it felt that without appropriate action and stimulation, including the possible establishment of a Multicore Institute, Competitive Actions and encouragement within academia for research in the area, UK competitiveness would be seriously impacted.

3.5. Closing Remarks

MCPs will change the future of programming and the development of software applications. MCPs will have a profound impact on many sectors central to both to existing and emerging industries and to Digital Britain.

The UK has existing expertise in relevant areas which it is failing to exploit at present. The meeting strongly recommended that this expertise be built upon. It also recommended short and longer-term actions to address current shortcomings in awareness and skills. This is necessary to maintain economic competitiveness in the exploitation of IT.

APPENDIX A: WORKSHOP POSITION PAPER

The following is the text of a paper sent out in advance to workshop participants in order to focus and stimulate the discussion:

Introduction

The migration to multicore processors (multicores) began in the early 2000s as a means of reducing the power of devices whilst continuing to increase their performance. multicores are widespread and used in most electronic devices from PCs, set-top boxes, network switches, mobile communications devices, desktops and servers to supercomputers.

Multicore affects everyone.

Multicore not only has an impact on processor architecture, but also system design; programming paradigms and design; and programming tools. multicores offer new opportunities for high-throughput applications in areas such as imaging and the information industries; multicores will also permit more sophisticated user interfaces to complex applications. Thus the technology presents significant challenges as well as substantial benefits for those who can be first to exploit it effectively.

The UK has strengths and relevant experience relating to multicore. The majority of end-users remain unaware of the impact that multicore will have on the IT industry over the next decade. If those at the leading-edge of multicore research and development are supported and encouraged and the wider end-user community is made aware of the benefits of multicores, UK industry will be able to take advantage from will be a transformation of computing.

The Impact of Multicore

The hardware industry

Core counts will grow and processors will become heterogeneous, including a number of standard CPU cores together with graphics processing units (GPU) and specialist cores to deal with specific functions (e.g. encoding, statistical analysis etc). This leads to challenges in developing interconnects at both chip and system levels, as well as in managing cache and memory access. It is often said that “cores will become the new transistors”; but well before that scale of integration has been reached the hardware industry will be faced with significant challenges. For example, processor yields will drop and the mean time between core failures will decrease. New models for fault-tolerance and for producing reliable devices comprising unreliable components will need to be developed.

The software industry

Multicore will bring many challenges to the software industry. The problem is not simply how to program the quad-core devices of today, but much more how to program the systems of tomorrow. These will include tens or hundreds of heterogeneous cores: they will have multiple levels of cache; and complex memory access. Understanding data location will be crucial to delivering good performance. Existing applications will need re-engineering. However, we do not yet have the necessary set of programming paradigms, languages, tools and libraries required to support these tasks. Much effort has been expended so far, but with only varying levels of success and portability.

End-users and developers

The necessary development tools to support multicore end users and developers are not yet available. While some applications will be able to be reworked to exploit multicore, other will have to be rewritten from scratch. The impact of a lack of appropriate tools to deal with the issues that multicore raises for many end-users and commercial applications developers cannot be underestimated.

In many sectors applications are used for decades and many mainstream applications are only upgraded once every three or four years. Unless applications can be future-proofed, neither commercial developers nor end-users will be able to exploit fully the benefits of new devices. The UK can benefit significantly if it can develop tools that increase portability across generations.

UK Multicore Analysis

At present the UK lags behind other countries, both in the EU and beyond, in addressing the issues that multicore technologies raise. The UK-based multicore hardware industry is built around a small number of companies, none of which (with the exceptions of ARM, ARC and Picochip) have achieved significant global market share. The UK software industry is also small with a variety of relatively minor companies and research institutions offering products and services. The UK has, however, a number of major global players, particularly in the embedded space, which form part of larger multi-national corporations.

Strengths

The UK has recognised expertise in a number of areas of relevance to multicore, including:

- embedded computing and hardware design
- high-performance computing
- many areas of academic Computer Science
- potential heavy multicore users in sectors such as media, networking and telecommunications, financial services, pharmaceuticals and biochemistry

The UK has 20 years of parallel processing leadership that has underpinned the development of distributed computing, the Grid and the emerging Cloud paradigm. This expertise is of fundamental importance to multicore.

During the last three decades of the 20th century, the UK developed considerable experience in the design of hardware using parallel technologies. Much of this expertise is transferable to current and future generations of multicore. Today, with the exception of a handful of companies, the UK has failed to maintain its global position. However companies, such as PicoChip, XMOS, ARM, ARC and others continue to create innovative products. A further tier of companies create custom multicore systems for specialist sectors. There is a clear opportunity to develop the market and grow indigenous capability to the economic benefit of the nation.

The UK has a long track record in many areas relevant to multicore and has, in the past, invested considerable amounts in relevant technologies such as parallel processing[15]. This led to a wealth of expertise in the 1980s and 1990s across several areas of software and hardware development. The consolidation of this investment faltered in the 1990s with the advent of Java and other internet-based technologies.

Weaknesses

The weakness of the UK computer industry with regard to multicore can be summarised as:

- It suffers a lack of focused activity in the area;
- It has poor support in terms of funding for innovative projects, both for industry and academia;
- Few trained programmers with relevant skills are coming out of educational institutions, far fewer than ever before;
- Many of those with relevant expertise have gone abroad, to Europe and to the US because of a lack of opportunity in the UK;
- With one or two exceptions, the UK lacks a globally competitive hardware industry to stimulate industries providing tools and technologies to build multicore applications.

Opportunities

The opportunities for the UK are:

- The multicore market is at an early stage of development and therefore there remains an opportunity to develop new businesses in new areas of economic activity;
- It has a record of excellence in multicore, parallel processing and closely related areas;
- It has given rise to or hosts a wide variety of commercial organisations for which multicore will be or already is an important enabling technology.

The existing investment in technologies and people offers a strategic opportunity for the UK to build upon. To take an example, much has been done on optimisation of code for multicore devices among members of the high-performance computing community. This community offers considerable expertise from which lessons can be learnt that are applicable across a wide spectrum of sectors; similarly, there are also techniques that can be learnt from the expertise of the embedded world in applying multicore technologies.

For the UK this wealth of expertise offers an opportunity to build new industrial sectors and new enterprises.

Threats

The major threats are:

- The UK has been slow to react to the market opportunity afforded by multicore devices;
- The UK's European and economic competitors are already active in this area and are investing more heavily than the UK;
- The UK is not participating in European and other partnerships to the same level as its competitors, surrendering its potential competitive advantage;

The present lack of direction in the industry with regard to software tools and programming paradigms mean that industrial giants are driving the market, potentially closing off areas of software activity to smaller companies such as those in the UK.

Conclusion

The emergence of multicore as the technology of preference for future generations of microprocessor devices presents the UK with an opportunity to develop new economic capabilities at a time of financial crisis. This workshop will examine what those opportunities are and how all the stakeholders represented at the meeting might exploit this new market.

REFERENCES & ENDNOTES

[1] See http://www.chathamhouse.org.uk/about/chathamhouserule/

[2] We use the term "multicore" as a generic term to cover a wide range of architectures, all of which have more than one core at their heart: these range from the "simple" symmetric architectures of AMD through to complex asymmetric architectures of the sorts often found in embedded systems. Within this broad spectrum are included other types such as Graphical Processor Units (GPUs) and IBM's Cell Processor as well as Intel's proposed Larrabee Processor . Core counts can run from two and four in portable, desktop and server systems, to hundreds and in some specialised cases thousands of cores.

Across this wide range there are also a wide variety of programming models, from day-to-day applications such as Word, Excel through to much more highly specialised ones, often of a more dynamic nature.

In this paper "multicore" is used as a portmanteau term covering these and others, unless the context makes it clear to the contrary.

[3] Digital Britain Final Report, June 2009 ("The Carter Report"), Department for Business Innovation and Skills & Department for Culture, Media and Sport, London 2009

[4] Source: FAST GmbH &TUM "Study of Worldwide Trends and R&D programmes in Embedded Systems" for The European Commission, 2005 at: ftp://ftp.cordis.europa.eu/pub/ist/docs/embedded/final-study-181105_en.pdf

[5] Source: ARM, 2009

[6] Quoted at http://cordis.europa.eu/ist/embedded/facts_figures.htm#1

[7] NOTE: The term "Virtualisation" is used in several different ways in the IT industry. Here it is used in the following sense, that of creating an abstract view of the underlying hardware, which hides the details of that hardware from those building applications to run on it. An analogy is to be found in the Java Virtual Machine ("JVM") where the JVM offers a standard interface for the developer to work to. The details of the underlying hardware are thus hidden from the developer.

[8] Concertant Internal Research,2009. These figures only include a partial allowance for necessary effort to re-implement applications etc with changes in rapidly evolving hardware and may be considered a low-end estimate. Concertant will provide more detailed figures later in 2009.

[9] Concertant estimates this figure to be substantially in excess of £500 million at today's prices. (Concertant Internal Research, 2008)

[10] This was developed through companies such as ICL, Inmos, Parsys, Meiko, NAG, Topexpress, Quadstone and many others; the DTI's Alvey Programme and its Parallel Applications Programme with its various centres; through various EPSRC programmes and projects; through academic centres of excellence such as Edinburgh, Imperial College, UCL, QMW, Manchester, Southampton and others; and through the participation of these and others in various ESPRIT, Framework, RACE and other programmes. The UK long held a world-leading place in parallel

processing both in hardware and software.

[11] The Concertant Annual Multicore Survey, 2008, http://www.concertant.com/multicoreSurvey2008.html

[12] See, for example,the Concertant Annual Multicore Survey (op. cit.)

[13] If core counts per device rise at anticipated rates, within the next fifteen years the mean time between core failures on a single chip will drop from its present value of years to mere days. (Concertant Internal Research, 2009)

[14] Quoted by Edinburgh Parallel Computer Centre, quoted in EPCC News 2009 see: http://www.epcc.ed.ac.uk/wp-content/uploads/2009/06/EPCCNews65.pdf

[15] Concertant estimates that this figure is in excess of £500 million at today's prices; the investment being made through a variety of UK, European and industrial initiatives (Concertant Internal Study, 2008) over a period from the mid 1980s on