HPC Systems Procurement Best Practice

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Abstract

The procurement of High Performance Computing systems is a complex process which seeks to meet a range of technical and financial targets with an optimal solution that maximises the benefits to the potential users whilst minimising risk. At the heart of the procurement process is the need to define the requirements of the system – is it to procure a test vehicle for assessing new technologies, provide a solution to a specific application or provide a general solution to a broad range of applications? Is the expectation to have high availability, minimise the acquisition or running cost, maximise the capabilities, minimise the amount of time it takes to solve a problem, or a mix of the above? Once the requirements have been decided and quantified the appropriate procurement route needs to be selected among a spectrum of possibilities ranging from pre-commercial procurement to stimulate Research and Development into innovative technologies to open procurements where the requirements could be met by current technologies. The various offerings need to be evaluated quantitatively, according to pre-defined criteria, in order to determine the Most Economically Advantageous Tender prior to signature of contract. Then acceptance of the system is usually performed on site through the completion of appropriate benchmarks. The management of commercial and technical risks is paramount to the success of the project in terms of securing quality solutions to time and to budget. The purpose of the white paper, produced within the PRACE IIP project, is to address these issues based on the experience of PRACE partners in terms of procuring large systems.

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Abstract .................................................................................................................................................. 1

1. Introduction ....................................................................................................................................... 3

2. General issues to be considered in procurements ......................................................................... 4

2.1. Requirements .................................................................................................................................. 4

2.2. Flexibility ......................................................................................................................................... 5

2.3. Pre-Qualification Questionnaire (PQQ) ....................................................................................... 5

2.4. Lifetime costs .................................................................................................................................. 6

2.5. Value for money maximization ..................................................................................................... 7

2.5.1. Benchmarking .............................................................................................................................. 7

2.5.2. Acceptance................................................................................................................................. 8

2.5.3. Risk ............................................................................................................................................... 9

2.5.4. Contractual aspects ................................................................................................................... 10

3. Procurement procedures .................................................................................................................. 10

3.1. Open procedure ............................................................................................................................ 11

3.2. Restricted procedure .................................................................................................................... 11

3.3. Competitive dialogue procedure ................................................................................................. 11

3.4. Negotiated procedure ................................................................................................................... 11

3.5. Pre-commercial procurement ...................................................................................................... 11

3.6. General constraints and applicability ......................................................................................... 12

4. Experience from PRACE partners ................................................................................................ 12

4.1. Requirements and constraints specification ............................................................................... 12

4.2. Flexibility and options .................................................................................................................. 12

4.3. Costs ............................................................................................................................................... 13

4.4. Internal processes and procedures ............................................................................................. 13

4.5. Time schedule, contract and negotiation .................................................................................... 13

4.6. Benchmarking and acceptance .................................................................................................... 13

4.7. Evaluation ....................................................................................................................................... 14

5. Risk management ............................................................................................................................ 14

6. Pre-commercial procurement (PCP) ............................................................................................. 17

7. Key recommendations ..................................................................................................................... 19

8. Conclusions ....................................................................................................................................... 19

Acknowledgements .............................................................................................................................. 19
1. Introduction

Within this White Paper we summarise experiences from various procurements within the PRACE project partners, with the intention to inform best practice. The main stages of procurements usually include:

- Justification in terms of a science case defining requirements and a business case securing the required finance.
- Translation of the science objectives into mandatory and desirable technical requirements of the system taking into account the market’s capacity to supply.
- Determination of the most appropriate procurement strategy - for example separate tenders for hardware, systems support and scientific support or procurement of a single service covering all of these aspects.
- Selection of the most appropriate procurement procedure compliant with national and international law to meet the objectives of the procurement. For example, research and development into novel technologies (possibly pre-commercial procurement), procurement of systems based on current technologies to meet evolving or specific requirements (negotiated procedure) through to procurement of fairly standard high-availability systems that meet the needs of a broad community (open procedure).
- Development of a Pre-Qualification Questionnaire (PQQ) to filter potential suppliers according to commercial considerations overviewing technical capabilities and financial standing.
- Evaluation of the responses to the PQQ, shortlisting of suppliers and request to successful suppliers to provide responses to a Request for Proposals (RfP) that includes information about the evaluation criteria that will be used.
- Evaluation of the responses to the RfP and possibly additional interactions with the candidate suppliers according to the selected procurement procedures. This results in a preferred supplier who enters detailed contract negotiations. A reserve candidate is also possibly selected should negotiations fail with the preferred bidder.
- Installation, acceptance and pilot use.
- Contract closure and assessment of lessons learnt.

The specification of the technical aspects of the system should include:

- General requirements – positioning the system with respect to a range of application performance metrics, infrastructure requirements, research, development and service objectives including availability and ease-of-use.
- Flexibility of procurement – defining the goal of the procurement from a technical point of view, especially in terms of performances during the lifetime of the system, single delivery vs. phased delivery, cost options to upgrade and/or explore new technologies on vendor’s roadmap.
- Costs – split between capital – buying a system and required upgrades to infrastructure, recurrent – purchasing access to a system rather than owning it, running costs encompassing electricity, maintenance and support – defining which parts of the Total Cost of Ownership (TCO) are considered in evaluating the value for money.
- Risk minimization – assurance of sustainability, on-going competitiveness of supplier with respect to general HPC market and with respect to the specific procurement, warranties and guarantees. Risks arise in different categories such as: institutional/societal, financial, market, technological and other that need to be identified, assessed and evaluated according to their severity, probability and magnitude, and possible mitigation measures identified.
- Maximize value for money – benchmarks and availability acceptance tests, added value and risk transfer.

In the following sections, assuming that the science case and business case and financial constraints have been specified, we explore general issues in terms of requirements specification, and discuss the various procedures that can be used to purchase systems. We then summarise the information gathered by means of questionnaires submitted to various PRACE partners about recent procurement experiences. We address the issue of risk management which needs to be managed at each stage to ensure that quality, time and cost constraints are met. Finally we outline the pre-commercial procurement approach defined by the European Commission in order to foster the Research and Development of new technologies to accelerate the speed at which HPC systems can attack problems of societal, economic and scientific impact and how Europe can secure a strategic capacity to supply these capabilities. We close with a few general conclusions and recommendations on procurement best practice.
2. General issues to be considered in procurements

The general issues to be considered in any procurement should include:

- **Requirements** – which usually addresses a spectrum of applications performance, availability and ease-of-use requirements depending on the objective of the procurement:
  - a stable production platform that will deliver good performance for a general set of applications for a broad range of users with mixed HPC experience;
  - a specific architecture that will deliver very high cost effective performance for a limited range of applications with an experienced user base; or,
  - a system for conducting experimentations in order to inform innovation of new designs for future generations of systems.

- **Flexibility of procurement** in terms of possible phased delivery – should the full capacity be installed from the begging? Is evolution of the system during its lifetime desirable and allowed in the RfP? How to evaluate the integrated performance in this case.

- **Minimisation of the risk of supplier default** – assurance of sustainability and on-going competitiveness of supplier with respect to general HPC market and with respect to the specific procurement through prequalification questionnaires or warranties and guarantees.

- **Lifetime costs** – it is important to consider total lifetime costs in evaluating value for money. These should include not only the cost of the system per se but: maintenance; system support; infrastructure (e.g. special floor, cooling, uninterrupted power supply, air and water quality); running costs in particular electricity and system support costs.

- **Maximisation of the value for money** – Most Economically Advantageous Tender to be evaluated considering benchmarks performances; availability; acceptance tests; risk transfer and added value.

2.1. Requirements

In preparing the requirements there should be extensive consultation with the vendors at least a year ahead of time about systems that may be available over the following 5 years. This consultation, usually referred to as a “market survey”, needs to be conducted in a way that avoids distortion of competition at a later stage.

Requirements are typically categorized into groups including technical, financial and future technology roadmaps. A target date for the commissioning of the system needs to be defined. Some flexibility should be built into the procurement to take advantage of new components or architectures that may become available on a relevant time-scale; the market survey should provide key information on this topic.

The requirements specifications can describe the need for a range of systems to meet the needs of a broad range of users undertaking a spread of science with many hundreds to many thousands of users. A subset of these users may have capability applications requiring access to large amounts of the system resource be it memory, compute or disk at a given time. Another subset of users may require access to sustained performance, high throughput for capacity users, systems integration and high availability. Accommodating different subsets of users with different requirements on a single system can result in a conservative procurement strategy – purchasing commercially available systems form large companies with appropriate support infrastructures rather than investing in novel technologies.

It is sensible to include a test system in the requirements specification, enabling system and application software to be evaluated in a realistic environment before being rolled out onto the production platform. It is desirable that the test system is delivered before the main system as this enables the development of systems management procedures and initial optimisation of applications. This may not be possible when the system is implementing brand new technologies. However, even in this case, a test system may be useful during the operation of the system especially for testing upgrades of the system software.

Depending on the main system specification it is also sensible to specify a front-end system that can be used for pre and post-processing of output. This possibly implies that a fraction of the system has high memory nodes with enhanced I/O to the filestore, another solution could be to procure a separate system for this function

Accurate specification of site requirements is increasingly important with a clear understanding of peak versus sustained power, footprint and weight, cooling requirements and detailed airflow and/or fluid coolant modelling, particulates specification and fire suppressant requirements.

The specification of technical requirements usually follows the development of a project, using a formal project management methodology, and should consider:
• hardware including systems architecture and sizing;
• I/O performance and global storage sizing, internal and external to the system;
• post processing and visualisation equipment and/or strategy;
• software including operating system, management and programming environment;
• operational requirements including installation constraints;
• maintenance and support requirements;
• training and documentation requirements;
• delivery requirements.

A subset of the technical requirements, relating to system sizing, includes specific requirement values, which unless otherwise stated, are minimum values to be met and allow the vendor to offer better values. Desirable requirements are so categorised to give vendors the option of meeting them or not and to provide the opportunity for vendors to differentiate themselves from the competition.

2.2. Flexibility

In an HPC procurement it may be difficult (if not almost impossible) to look many years ahead in terms of both application requirements and what the market may be able to deliver. So it is important to include in the provision through the timescale of the procurement. This could include:

• Specifying a profile of increasing requirements as a function of time with key system parameters such as compute performance, memory, disk, backup and I/O performance.
• Options for purchasing reduced or increased system configurations, increased benchmark performance, filesystem size and performance, memory, interfaces, future technology evaluation systems, additional on-site support.
• Allowing slippage in delivery for some compensation in system performance.
• Accommodating technological changes that may be proposed to save money, to improve performance, save energy or accommodate increased capability and capacity needs.

2.3. Pre-Qualification Questionnaire (PQQ)

In a complex procurement it is good practice to have at least a two phase process the first of which aims to obtain sufficient information to enable the procurer to evaluate the suitability of a potential supplier to meet its requirements—typically embodied in a Pre-Qualification Questionnaire (PQQ)d. The intention is to arrive at a shortlist of potential suppliers to respond to a formal Request for Proposals (RfP) against the requirement. The questionnaire is usually structured in two parts: Company Corporate Information and Information Relating to the Specific Requirement.

A PQQ normally requests Company Corporate Information in the following areas:

• Company details and history.
• Organisation and Management.
• Capabilities.
• Financial status.
• Quality Management.
• Supply Chain Management.
• Legislative Compliance.

and information relating to the Specific Requirement including:

• Contact details.
• Staff qualifications and skills – resumes.
• Added value from other resources and activities.
• Activities to be subcontracted.

Cf the PQQ elaborated during preliminary phase of PRACE project at: http://www.prace-ri.eu/IMG/pdf/D7-6-2.pdf
Financing – in particular of capital investment.

Similar contracts undertaken elsewhere and evidence of performance.

References from major international centres worldwide.

The weightings for the evaluation of a response to a PQQ vary according to the type of system being procured, for example, whether access to reliable proven systems or the exploitation of novel architecture systems is the objective.

In terms of weightings one approach could be to advise that during the first phase of the selection some 3 to 10 candidates will be chosen for entering into, for example, a competitive dialogue phase.

Focussing on a subset of the responses in the PQQ, sensible weighting criteria might be:

- up to 3 points for economic and financial capacity reflecting relevant sales, on a sliding scale;
- up to 2 points for technical accreditation standards e.g. ISO, on a sliding scale;
- up to 2 points for maintenance/support location and numbers;
- up to 3 points for reports from reference sites.

Suppliers with say more than 5 points would then be invited into a competitive dialogue unless they get a mark lower than a threshold value on one or several major criteria.

2.4. Lifetime costs

The Total Cost of Ownership (TCO) of HPC systems is an important figure that will need to be derived during a procurement process and matched to the available budgets – both capital and recurrent. Items that need to be assessed include the following costs:

- acquisition;
- maintenance;
- infrastructure upgrade;
- power consumption for the system including cooling.

Depending on the case, additional items may have to be added, for example:

- training;
- user application support;
- exploitation.

These will vary significantly depending on the nature of the system e.g. general purpose or novel architecture. There may well be site specific issues such as the need to integrate the system into the current mechanical and electrical infrastructure, the systems and data infrastructure, and the breadth and depth of skills required for systems management.

A breakdown of expenditure is typically:

- 5-10 % of the budget on infrastructure – building, technical facilities and maintenance. It is quite difficult to capture the real cost of this in practice as the machine room may already exist, the capital cost may be depreciated only over the period of the current system’s operations or over a building’s natural lifetime, or the new system may need to fit into the existing infrastructure. Given that most systems are designed to fit into ‘normal’ air-cooled or liquid cooled computer room this category can usually be categorised as a mandatory – the system can fit into the proposed infrastructure (or the costs of adapting the infrastructure are marginal) or the costs of adapting the infrastructure are so large as to rule out the vendor.
- At least 10% of the budget on running costs such as electricity and systems management – again difficult to cost where the computer room may be sharing existing electrical and cooling infrastructure and the system management effort may be amortised over similar systems. The key metric here is the systems power and how that maps into usable Flops\(^6\).
- 65-70% of the budget on the system – supercomputer plus related IT equipment and maintenance.

\(^6\)Flops stands for one floating point operations per second.
• 20% of the budget on applications support for end-users.

The key issues that the vendor can respond to are:

• Cost of the equipment – these includes system costs and infrastructure costs. The latter are either marginal in the sense that the system is being integrated into a current facility with specific wiring and cooling cost or require a major upgrade to the facility which will make the system uncompetitive.

• Cost of maintenance – depends on the reliability required of the system and the capabilities of the supplier. Usually included in the capital cost.

• System electricity consumption – ignores cooling requirements as this is usually defined by the infrastructure. The important metric here is the useable Flops/Watt ratio as this really dictates the output from the system. As a practical measure, consumption during the running of the Linpack test if often used as a reference for large supercomputers that are used for heavy production loads. Clearly, there is no point having high peak Flops and low energy consumption if the applications cannot take advantage of them.

• Ease of support and use - varies according to whether the system is a general user service on an established architecture (high) or on a novel architecture system (low).

The mandatory issues here are affordability covering both capital cost for the system and its recurrent costs. Best practice would point to specifying the overall budget in terms of budget for both capital and recurrent hence specifying the Total Cost of Ownership and optimising the most economically advantageous tender through appropriate weighting of the technical capability, TCO, performance, risk transfer and added value as discussed below.

2.5. Value for money maximization

As stated in paragraph 2.3, in a complex procurement it is good practice to have at least a two phase process, the first of which aims to obtain sufficient information to enable the procurer’s to evaluate the suitability of a potential supplier to meet its requirements and contribute to the minimization of risks, the second one aims at selecting the Most Economically Advantageous Tender and at signing the best final contract with the selected supplier. This chapter describes the main steps for the second phase that do vary according to the procurement process chosen.

Submissions to the RfP from vendors should be assessed using a set of pre-defined evaluation criteria, typically organised as an “evaluation matrix”. The evaluation criteria are made publicly available beside the RfP and typically contains a number of mandatory and desirable requirements with the latter evaluated on a sliding absolute or relative scale.

2.5.1. Benchmarking

Performance of the offerings is best assessed through a formal benchmarking process. Centres procuring systems will obviously have a firm view on applications requirements on their systems in the short to medium term. Benchmark suites with synthetic benchmarks and representative application benchmarks should be assembled. There are plenty of synthetic benchmarks available today, as well as application benchmarks ranging from single codes developed and maintained by single Institutions (more or less adopted worldwide) to integrated and complex suites provided by joint initiatives such as the PRACE Application Benchmark Suite (updated as the Unified European Application Benchmark Suite). Within any specific procurement the user workload exploiting these and potentially new applications codes will need to be assessed and appropriate datasets constructed. This should give the vendors the opportunity to provide concrete performance and scalability data.

The performance of systems is usually assessed as a hierarchy of benchmarks. As an example the hierarchy could include:

- The most common benchmark for peak/sustained performance measurement, used to rank systems in TOP500 worldwide list.


• system component tests such as STREAM (main memory performance), P-SNAP (operating system noise test), SkaMPI (general communications/interconnection), IOR, Metabench (file system stress and behaviour) and NetPerf (general networks);
• kernels which run as serial through to full core count MPI on a node – tests memory bandwidth for various classes of algorithm (seven sisters);
• full applications;
• composite tests measuring throughput such as SSP (Sustained System Performance – geometric mean of processing rates for a number of applications multiplied by number of cores in system – for highest core count runs), ESP (Effective System Performance – which measures the achieved job schedule against the best possible job schedule) and CoV (Coefficient of Variation – which measures the variability of job run times).

The SSP provides a measure of the mean Flops rate of applications integrated over time and thus takes account of hardware and software upgrades. The selected vendor is required to meet benchmark performance levels at acceptance and throughout the lifetime of the contract.

The overall mark for benchmark performance can be assessed using a variety of formulae capturing relative performance weighted by importance to the workload of the service. The final figure can again be renormalized linearly or non-linearly to a scale of zero to 100%, reflecting the best performance.

Usually, responses to the RfP are based on the commitment of the suppliers to provide a minimum level of performances of the set of benchmarks. The commitment is often the result of performance simulations conducted by the suppliers based on existing systems/technologies, the simulations being used in order to extrapolate the performances to the system that is proposed and that doesn’t usually exist at the time the responses are prepared.

2.5.2. Acceptance

The acceptance tests are done once the system is delivered and installed on site and are defined in the contract. The purpose is to check that contractual commitments are reached. They need to address clearly and in a systematic way the Technical Requirements. The different types of requirements can also be categorised as to whether they address the following. The typical means of verification are given in parentheses.

• Capacity: for example minimum applications memory per processing unit, minimum global disk storage (file system utility), maximum global file system partition sizes (file system utility), maximum number of concurrently opened files (run an MPI job which opens requisite number of files), archive and back-up sizes (interrogate storage management product), maximum floor area and floor loading (weigh racks before installation), maximum power dissipation for system and cooling (meter racks and cooling infrastructure).
• Performance: for example minimum sustained Flops (Linpack benchmark), minimum memory bandwidth (STREAM benchmark), memory latency (page refresh), maximum point-to-point message passing latency (SkaMPI tool), all-to-all bandwidth (SkaMPI tool) and barrier latency (SkaMPI tool), sustained read/ write bandwidths and latencies (MPI-IO API/implementation, IOR benchmarking tool, Metabench tool) for all processors (as above for local I/O for scratch space), external networks connectivity and performance (GRIDftp), O/S memory/ CPU usage and jitter (measure with no applications), large page size efficiencies (test on selected benchmarks), archive and backup performance (read/ write varying file sizes from global file system to archive). System resilience, start-up and shut-down tested during availability tests, support and maintenance arrangements can only really be tested in full production since the system is unlikely to fail during the acceptance period.
• Functionality: compliance with standards – 32 bit, 64 bit, ECC memory, UNIX-like POSIX O/S, multiple system images (during acceptance), security (audit). Applications development environment for compilers, libraries, scripting languages, debugging and profiling tools (apply to specific benchmarks). Environment needs to support a 'module' environment to meet the requirements of different applications. On the systems side, schedulers and monitoring diagnostics can be tested with throughput benchmarks and systems administration functions can be tested through shut-down and start-up exercises. Accounting and reporting utilities can be assessed whilst early users are

i The MPI standard defines the syntax and semantics of a core of library routines useful to a wide range of users writing portable message passing programs.

j The most common benchmark for peak/sustained performance measurement, used to rank systems in TOP500 worldwide list.
accessing the system during the acceptance tests. Documentation is required for all of the major system utilities and can be viewed by inspection.

- Flexibility: upgrades to current system and future technology roadmaps, field upgradability and time to upgrade.

The analysis above should apply equally to systems with multiple components e.g. test and development systems, pre and post-processing systems and visualisation capabilities. There may be additional requirements to integrate the system into the current file system infrastructure and require interoperability not just between the components of the procured system but also with a range of other vendor offerings in particular clients for other file systems. Clearly the specification of the technical requirements needs to be as specific as possible to meet the needs of the intended user community. Many of the requirements can be assessed by inspection or by using basic utilities or by running standard benchmark packages. Some of the requirements may need to migrate between explicit mandatory requirements and desirables, depending on whether the system being procured is for a broad use community or for a specific application, with a community prepared to soften its requirement for standards or up-front demonstrations of performance.

In addition to the baseline Technical Requirements which underpin the capabilities of the system, other criteria need to be considered e.g. service providers are particularly interested in the medium to long-term reliability, availability and serviceability of the system, while end users are interested not only in being able to routinely access the system but also in the performance of the system on their applications.

In terms of a timetable, the customer may wish a phased demonstration of the capabilities of the system. This may include:

- On-site test after installation (which is always required) - including all hardware installation and assembly, burn in of all components, installation of software and approved production environment, tests and benchmarks addressing functionality, performance, reliability and quality and run benchmarks to demonstrate performance commitments. Systems tests should demonstrate a reasonable amount of time to boot the entire system from a cold start to the production state and to shutdown the system.

- Factory Test prior to shipping covering power up and down, Operating System commands, monitoring software, reboot functions, power cycle from console, configuration testing benchmarks and a variability test expressed as some meeting some maximum percent variance over a number of days. It may not be possible for some vendors to test the full system because of limitations on the factory’s power and cooling or because of a tight delivery schedule. However running tests and verifications even on a subset of the system makes possible to anticipate possible problems before on-site delivery and therefore is desirable.

- Availability tests usually run for 10-30 contiguous days in a sliding window of 20-60 days and require typically 98% availability – often running a selected system load. Failures taken into account for computing the availability may include unavailability of nodes, inability to access the file system, inability to login, unavailability of full switch bandwidth, inability to launch batch submission.

- Functionality demonstrations are run on the configuration that will go into production and include remote monitoring, power control and boot capabilities, network connectivity, file-system functionality, batch system, system management software, program development environment and Operating System functionality.

It should be noted that an aggressive approach to acceptance tests can be counter-productive resulting in very conservative proposals from the vendors which seek to minimise the risk that they take a long time to secure acceptance. A partnership approach may be more sensible for accepting novel architecture systems. It is always useful to specify reasonably flexible benchmark suites whereby marginal under-performance in one area may be compensated by over-performance in another area. Vendors should be given a reasonable period – say of order 180 days – to meet the most demanding availability tests which may run over a rolling 30 day period. The impact of delayed acceptance on the vendor’s bottom line should not be under-estimated – even for the larger vendors. The acceptance tests should also be consistent with the detail of the maintenance contract.

2.5.3. Risk

Risk management will be discussed more formally in section 5 but it is worth mentioning that risk management should be integrated into all activities within the procurement and that risks should be assessed according to their potential likelihood and impact and be assigned “risk owner” for managing them. The PQQ and RfP and acceptance test should mitigate the following risks in terms of minimising the likelihood of:
- risks that may prevent the system from becoming operational: a supplier ceasing to operate or where a system fails to pass its acceptance tests;
- risks that may delay the system operation: delays in the production process, delays in sub-contractors roadmaps;
- risks that may limit the reliability, availability and serviceability of the system: section, lack of key functionality or performance of e.g. global parallel file system; power or cooling requirements may exceed expectations or the system may not be as reliable as needed;
- risks associated with usage exploitation of the system: errors in software and hardware or applications performing unexpectedly badly.

The various risks manifest themselves to the service provider in terms of:
- potential system demand/load risks (over demand or under-utilisation);
- price risks (need for extra infrastructure);
- additional electricity costs;
- timescale risks (failure to deliver the service on time to the community);
- performance risk (applications do not achieve the expected performance or the system is less reliable than planned).

During the evaluation of tender responses the likelihood of these risks can be assessed for each vendor and marked and weighted in a manner similar to the evaluation of the technical requirements. The contract needs to incorporate various mitigation measures and appropriate penalties should the risks actually be realised. In terms of risk management, key risks are typically held in a register and reviewed on an appropriate timescale. These registers should include various actions to mitigate many of the risks which can involve the vendor, the service provider at appropriate levels of escalation.

2.5.4. Contractual aspects

Typically a fixed term contract with line items for a test system, main computer systems, maintenance and servicing, and performance metrics as a function of time and other negotiated features and deliverables is issued. Most contracts have a Change Control Procedure, named personnel, insurance, and priced options.

The contract needs a clear specification of the site preparation, subcontractor commitments warranties and representations, transferable software licenses, access to facilities and network policies and procedures.

Where performance metrics are mandatory it may be necessary to include charges for additional infrastructure, system support and running costs, should the tendered configuration need to be increased in order to reach the contractual performances.

It is also important to make sure that the conditions for performing the benchmarks which are critical in the contractual acceptance are completely explicit. Insist that benchmarks are run as-is, that is, with the supplied source code on the Operating System, run time libraries and numerical algorithm libraries to be supplied for operations as a mandatory requirement to benchmark applications and systems performance. It is also desirable to invite vendors to submit details of improved performance through code and systems management optimisations, which should be at the source code level and in terms of effort required, as this information is helpful in planning the amount of potential future user support effort required.

Usually, the contracts contain provisions for applying penalties or even for rejecting the system in case of deviation from the contractual specification.

3. Procurement procedures

The EU Procurement Directives (2004/18/EC of the European Parliament and of the Council dated 31st March 2004 on the coordination of procedures for the award of public works contracts, public supply contracts and public service contracts) set out the legal framework for public procurements. They apply when public authorities and utilities seek to acquire supplies, services or works; they set out procedures which must be followed before awarding a contract when its value exceeds set thresholds, unless it qualifies for a specific exclusion – for example – on the grounds of national security.
For planned purchases above the threshold value a Prior Indicative Notice (PIN) may (optionally) be published in the OJEUk Official Journal, typically at the beginning of a financial period. The PIN must contain as much as possible of the information normally published in a contract notice and must have been despatched to the Official Journal no less than 52 days and no more than 12 months before the date of despatch of the relevant contract notice. Below a summary of the different procedures currently allowed by EC Directive.

3.1. Open procedure

Anyone can bid: suppliers respond to a notice in the Official Journal, all interested suppliers will be sent an Invitation to Tender (ITT). Unless a PIN (see above) has been issued the purchaser must set a response date of a minimum 52 calendar days from the original notice date. Most organisations use this procedure whenever possible as it opens opportunity to the widest competition. This procedure is clearly inappropriate for the procurement of very technical high risk contracts, since there are in practice very few companies able to supply and the effort of reviewing tenders is large.

3.2. Restricted procedure

The number of tenderers (suppliers) may be restricted to at least 5, if available, and only those suitable applicants (assessed by a business questionnaire) invited to bid may do so. A minimum 37 days must be given for expressions of interest. Shortlisted suppliers will be sent an Invitation To Tender and allowed a minimum 40 days to respond (unless a PIN has already been issued). Most organisations will use this procedure when there is a probability of high levels of interested vendors in the supply market which would result in difficulties and inefficiencies in the tendering process.

3.3. Competitive dialogue procedure

Following an Official Journal Contract Notice and a selection process, the authority then enters into dialogue with potential bidders, to develop one or more suitable solutions for its requirements and on which chosen bidders will be invited to tender.

3.4. Negotiated procedure

A purchaser may select one or more potential bidders with whom to negotiate the terms of the contract. An advertisement in the Official Journal is usually required except for certain circumstances, described in the regulations. An example is when, for technical or artistic reasons or because of the protection of exclusive rights, the contract can only be carried out by a particular bidder.

3.5. Pre-commercial procurement

Pre-commercial procurement (PCP) was introduced as “an approach to procuring R&D services” in a Communication of the Commission of the European Communities in December 2007 with the intention of driving forward innovation in products and services to address major societal challenges.

The EU has enormous purchasing power in the order of B1700 € pa of which less than B3 € is used for procuring the research and development of new products and services. The US spends four times as much in areas such as health and energy. By engaging Europe’s public procurers in buying the development of new innovative products and services it is hoped that this will provide better public services and greater value for money and give European high-tech industry a chance to be the first to market.

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\(^1\)Official Journal of European Union

\(^2\)Two main sources of information about PCP are:

The goal of the PCP approach is to foster this engagement and to overcome some of the barriers to such an approach, for example, the fact that the European procurers are fragmented, averse to risk and may have to overcome legal barriers to cooperate across borders. We discuss this in more detail in section 6 below.

3.6. General constraints and applicability

Public Authorities typically have a free choice between the open and restricted procedures. The competitive dialogue procedure is usually only available where the contract cannot be awarded under open or restricted procedures (“In the case of particularly complex contracts”, according to the EU Directive). The negotiated procedure can only be used in very limited circumstances.

Under restricted, competitive dialogue and competitive negotiated procedures (those where a call for competition is required by advertising is advertised in the OJEU) there must be a sufficient number of participants to be selected to proceed to the tender stage to ensure genuine competition. The regulations require a minimum of five for the restricted procedure and three for competitive dialogue and negotiated procedures.

There are restrictions on the use of post tender negotiation under the open and restricted procedures – there can be no negotiation on price.

4. Experience from PRACE partners

In this chapter we summarise the outcome of a limited survey submitted to several PRACE partners involved in recent procurements. The contacted organizations are all providing HPC services and maintaining formal or informal continuous processes to keep themselves aware of the technology and the market. The trend is to maximize the return on investment so the consultations with the vendors are extensive and take place ahead of time on systems that may be available over the following 4-5 years. The vendors’ technology roadmaps are becoming a key factor; in fact the major organizations request multi-stage procurements, either in terms of technology upgrades or system extensions. Some institutions make the specification of the vendors technology roadmap with a potential system upgrade a mandatory requirement, some others make this an option. Technology scouting is a common practice and especially where technology upgrade is requested it is performed by means of prototype system installation.

4.1. Requirements and constraints specification

For installations of systems that are relatively new in a vendor’s roadmap (e.g. new architectures) or where a second stage procurement is required, it is sensible to include a test or prototype system in the Request for Proposals (RfP). This is needed in order to support porting of software and the integration of system management procedures during the forthcoming procurement cycle.

There is a new wave in the requirements of facility infrastructure requiring either adaptation and or renewal. Despite the fact that organizations are continuously adapting their facilities, no one has reported including facility requirements in their procurements. In general facilities are considered as a constraint during the specification of the RfP, so a correct specification of site requirements is increasingly important with a clear understanding of peak/sustained power, footprint and weight, cooling requirements and detailed airflow/fluid coolant modelling, etc.

Running costs, maximum investment cost (reflected by TCO) and total cost versus sustained performance ratio are the main constraints and key requirements.

4.2. Flexibility and options

Despite the procurer’s aims to foster vendors’ involvement in developing proposals for the solution, the procurers do not tend to allow a great deal of freedom during all the phases of negotiations. The regulations allow for a lot of flexibility during the initial phases of the Competitive Dialogue and that seems sufficient. No flexibility is allowed at the end: bidders and tenderers appreciate this because it tends to lead to clearer relationships between the counterparts. Some sites like to be well constrained from the beginning of procedure so they adopt the open procedure. Options to bid for sub-systems like I/O are encouraged. Options are requested to maximize the return on investment (ROI) over time, such as including a future system in the technology roadmap in the bid, to replace the initial system, as aforementioned. It is becoming increasingly important to hold special sessions with vendors during the procurement which are dedicated to physical and environmental constraints as we move to much higher power density racks, to systems that can vary power applied to racks according to the applications and the need to integrate variations in system usage tightly into the broader
facility management control systems Dismantling of systems subject to environmental requirements is always considered part of the lifecycle but may be optional in limited cases.

4.3. Costs

The procurement process is almost always cost driven. All the additional services and related costs tend to be considered in tenders. Facilities, facility management, operation of the system and user support are almost always considered apart and related costs don't account for the final evaluation of the offer, neither for the RfP. The main reason for this seems to be the long term of amortization for such goods compared to the short life of the supercomputers. In terms of operation and user support, sites differ largely: some (minority) request the bidder to offer services such as operations and user support but the majority of them only asks for training in order to provide operations and user support themselves. The motivations for the differences may include:

- costs for operations and user support are negligible compared to the total investment;
- operations and user support may involve confidential information;
- skilled personnel is a scarce resource – difficult to recruit and retain;
- core business of the various organizations requires a tight coupling between operations, user support and end-users;
- vendors are unable to provide the required support, so asking for that is perceived as a limitation to engage potential vendors.

4.4. Internal processes and procedures

Generally the initiation of the procurement process is driven by a formal or informal internal innovation cycle that is almost continuous. The amount of investment required implies funding of joint national projects and heavy national or regional political consensus. Roadmaps for effective funding span over several years. Key professionals involved in processes include system architects and application experts plus legal advisors. Legal support both from internal and external advisors is considered very important because of the complexity of the procedures and laws. The preferred procedure is Competitive Dialogue (of course with publication in the Official Journal of the European Union), because it allows discussion with vendors in order to adapt requirements to feasible products whilst optimizing the price over performance ratio. The flexibility of such a procedure during the initial stages is appreciated as much as the rigidity at the end of the procedure. All phases and interactions with vendors need to be well documented and checked. Some sites emphasize the use of Wiki pages (restricted web interaction and documentation exchange) in order to publicly interact with all the vendors simultaneously. Some sites have used framework agreements negotiated between the government agencies and the different potential vendors prior to the procurement phase. Other sites have used the Competitive Dialogue procedure to support a R&D phase, including the option to buy the final product.

4.5. Time schedule, contract and negotiation

The most common procedures used are the open and competitive dialogue, the latter is performed by means of a certain number of iterations/contacts with the vendors. It's typical to have 5 or 6 negotiation rounds with at least one face to face meeting per vendor. The whole process requires many refinement steps. The process typically takes eight months from the approval of the tender to vendor selection. A typical timetable might include:

- a political process that starts four years ahead the procurement;
- user needs are collected starting three years ahead of the procurement;
- when funding is approved (two years ahead), the RfP is started;
- competitive dialogue may take one year from RfP announcement to final contract.

Differences from the above picture are only found for smaller procurements.

4.6. Benchmarking and acceptance

Acceptance is mainly based on a set of benchmarks and functionality tests, which range from synthetic benchmarks to real applications and production scenarios, as described in previous paragraph 2.5.1. Some institutions prefer to specify absolute metrics in the RfP rather than benchmarks. The coupling between benchmarks and metrics is later agreed during
dialogue. Almost all organizations have a team involved in benchmark definition, implementation/adaptation and evaluation.

4.7. Evaluation

Evaluation procedures tend to focus mainly on TCO, having fixed the required performance expectation. Many other factors are also considered, such as additional services, migration paths, affordability for multiphase procurements, etc. One site expressed its decision strategy as based on “best performance for given TCO”. In general all key requirements/criteria are weighted and final evaluation is the result of the weighted sum.

In the following section we review risk management which is a vital component in all of the stages of a procurement.

5. Risk management

The management of risks is vital to a successful HPC procurement. Risks can occur at any stage of the project, for example, at the beginning:

- having too strict requirements may lead to not getting any acceptable proposal at all in response to a Request for Proposals (RfP). With a shrinking number of vendors in the HPC market there is an increasing probability of just receiving one proposal, which may be unacceptable. A strong association of a computing centre with one vendor may discourage other vendors from participating in a procurement.”

Through to the end where:

- vendors may protest and delay the procurement process. In the worst case it must be completely restarted due to a vendor request that has to be satisfied.

In a recent report\(^\text{m}\) carried out by an expert group set up by the European Commission Directorate-General for Research, with the subject: “Risk management in the procurement of innovation”, various risk management models and practices are analysed and presented. These models range from the simple “implicit risk management”, where risks are defined and managed by means of laws and external procedures, to a complex integrated risk management model summarised below:

- Identify Issues, setting the context.
- Assess Key Risk Areas.
- Measure likelihood and impact.
- Rank risks.
- Set desired results.
- Develop options.
- Select a strategy.
- Implement the strategy.
- Monitor and evaluate and adjust.

The expert panel assessed a classification of risks in (public) procurement and defined a map (see Figure 1 with reference to the procurement cycle). Within the PRACE project we have developed a Risk Breakdown Structure (RBS) which acts as a starting point for our classification. The result is depicted in Table 1 below.

Figure 1: Risk Map

It is widely perceived that Risk Management is not really a separate process. One can of course propose a big and complex procurement where one delegates the task of making a risk study and developing a management plan to the vendor.

With reference to the aforementioned risk classification and to the conducted survey, more or less all the surveyed sites identify two main categories of risks: financial and technical. For some respondents, financial risks are represented only by the vendor’s economic stability and trustworthiness. These are managed mainly by a pre-qualification questionnaire (PQQ). Awareness on the side of technical risks is very high and management of these seems to be more comprehensive than for other typologies.

The preferred way to mitigate technical risks is mainly by formal penalties as in the case of delays in delivery or underperformance on benchmarks. Contract termination is only considered by partners in extremis but no one reported this happening recently. Some sites have considered a set of risks related to: infrastructure, operational, usability/usage, fiscal and risks to multi-phase procurement (almost exclusively technical issues). The answers of the vendors to mitigation measures for the given set of risks entered into the qualitative evaluation of the offers.

Some sites have based their risk management on the EVB-ITⁿ standard and penalties proposed there are used for the procurement process. Some institutions have added special penalties in case of increased power demand with respect to the requested and declared specifications. The global picture is not uniform and technical issues dominate the field with very few exceptions. This seems to be sufficient to engage successfully in this kind of procurement, even for Petascaleⁿ systems. The main difference arises were R&D was included in procurement, so the request for a more comprehensive management plan was put in the bid as part of the procurement. That worked, but we have no information about the balance for the bidder/vendor in terms of risk sharing.

ⁿErgänzende Vertragsbedingungen für die Beschaffung von IT-Leistungen (Additional conditions of contract for the procurement of IT services). A German standard for IT public procurement.
ⁿSystems capable to perform more than one Pflops.
### Technical

- Contracted technical properties not available;
- Data centre doesn't fit requirements;
- Power or cooling exceed requirements;
- Reliability in requirements;
- HW and SW requirements don’t match.

### External

- Subcontractors and suppliers
  - Commercial risks (industrial situation of the vendor)
  - Technical risks originating at vendor and suppliers
  - Contractual risks, (contract fulfilment issues related to vendor: Delivery, Declaration of readiness, Functional properties, Performance commitments, Reliability)

### Organizational

- Dependencies
  - Coordination with on-going data centre infrastructural projects

### Management

- Estimating
  - Budget risks (Estimation)

### Complexities and interfaces

- Data centre and infrastructural complexities
- Delays due complexity of integration in data centre
- Programming styles and software too complex.

### Technology

- Utilization risks (HW and/or SW technology not enough mature)

### Regulatory

- Resources
  - Support staff

### Resources

- Planning

### Market

- Shrinkage number of vendors
- Staff shortage

### Funding

- Controlling
  - Funding risks (State, National and Supranational)

### Performances and Reliability

- System performance risks (SW and HW related)
- Reliability of HW and SW

### Environment

- Prioritization

### Quality

- Final Quality reflect usability

- WAN related risks

### Infrastructures

- Communication

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<th>Technical</th>
<th>External</th>
<th>Organizational</th>
<th>Management</th>
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<td>Subcontractors and suppliers</td>
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Table 1: RBS with detailed risks
6. Pre-commercial procurement (PCP)

As noted earlier, PCP typically occupies the product development pipeline starting with solution exploration, moving on to prototyping and then delivering a first limited volume of products or services (a test series). The products then enter into the realm of commercial roll-out and can be purchased through standard public procurement procedures. This type of R&D procurement strategy has been used heavily in the US in particular by DARPA and the Department of Energy to support R&D for supercomputers, addressing public needs with long-term procurement plans and a competitive multi-supplier approach. Best practice is to procure in the steps discussed above to reduce risk, involve multiple suppliers, gradually converge towards a solution best suited to the needs, work across borders, and develop larger markets and foster standards.

Access within these schemes is typically restricted to local industrial suppliers but has to be organised in compliance with WTO rules discussed in the: "Agreement on Government Procurement (GPA)" at http://www.wto.org/english/docs_e/legal_e/gpr-94_e.pdf).

Legally the procurement of R&D services falls under an exception of the WTO GPA and the EU public procurement directives built in accordance with the WTO GPA. For this exception to hold, the value of the pre-commercial procurement contract must consist by at least 50% of R&D services. Therefore, the value of any products procured in the contract (including test products) cannot exceed the value of the R&D services covered by the contract.

Under this condition risk-benefit sharing between the procurers and the suppliers can be organized and restriction of the tender to the European Internal Market is allowed. However, the recommendation of the Commission is not to use eligibility criteria of suppliers related to the domestic location of the company office and/or governance structure but rather to allow “companies from anywhere in the world to make offers regardless of the geographic location of company head offices or their governance structure [as] an open and effective way for Member States to promote the creation of growth and jobs in Europe without excluding non-European firms”.

Figure 2: Typical Product Innovation Life Cycle

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\(^p\) Article XV, section (e) of the GPA

\(^q\) Built « in order to incorporate the results of field testing and to demonstrate that the product or service is suitable for production or supply in quantity to acceptable quality standards »

The momentum behind the exploitation of PCP has increased significantly in recent years. In February 2009, the European Parliament adopted a resolution supporting the use of PCP by public purchasers and the use of PCP was given further support in May 2010 by the Council of the European Union on the occasion of a meeting of the Competitiveness Council. In April 2011, a “High level event on pre-commercial procurement – towards a smarter research and innovation procurement strategy for Europe” took place in Hungary.

Several European projects were launched in order to explore the practical implementation of PCP in different contexts. Among those, the P3ITS project has explored Pre-commercial Public Procurement for ITS (Intelligent Transport System and Services) innovation and deployment and through its WP2 Analysis of public pre-commercial procurement models and mechanisms.

Deliverable D2.1 of this project, describes the legal framework for public procurement and PCP and how procurement of innovation has been implemented in practice in different Member States in the EU including practical examples. The report notes that the use of PCP is not without obstacles such as the different tendering process laws in different countries and the cost of tendering versus the benefits, mixed (supply, works, service) contracts to establish thresholds and rules, the risk of supplier exclusion, and the subsequent commercial tender, in particular purchasing the developed product as part of the PCP contract. The report also gives suggestions as to how these obstacles could be overcome, for example: the contract will be categorised by its highest component – services, licensing of IPR at commercial rates, specification of functional requirements and notes that innovation can also be supported through other methods such as the negotiated procedure, design contests, framework agreements and competitive dialogue. These procurement procedures differ in a number of ways and apply to varying situations. However, they have one thing in common that differentiates them from PCP, which is, that they can all be used to procure the development service as well as the resulting solution. The authority is thus not forced to make a new tender for the procurement of the developed solution in commercial volumes, but can make such a purchase a part of the contract from the beginning.

So far, PCP has not been used, as far as we know, in HPC. Therefore, the call “FP7-INFRASTRUCTURES-2012-1” issued in July 2011 will likely initiate the first PCP in HPC as it requires the implementation of PCP in the PRACE 3IP project. In the PRACE preparatory phase and the PRACE-1IP phase one can identify the seeds of a pre-commercial procurement activity through the identification of forward-looking requirements for systems and the procurement of prototypes.

Using PCP could provide the PRACE ecosystem with an exciting opportunity to drive forward the development and innovation of HPC systems tailored to meet European requirements aimed at solving major societal challenges by:

- pooling the efforts of multiple procurers – in the first instance the agencies supporting academic research who are increasingly seeking to ensure economic and societal impact;
- stimulating indigenous supply through “locating relevant portions of the R&D and operational activities related to the PCP … in the EEA”; and,
- encouraging procurers to act over the mid-to-long term to define solution requirements for the required public sector innovation.

Regarding PRACE 3IP, the technical goal of the PCP that will be implemented during this project is related to “Whole System Design for Energy Efficient HPC”. This goal has been decided upon based on the technical work conducted during the PRACE preparatory phase and the PRACE-1IP phase. Working on such an issue is indeed of paramount importance for the construction of future very large-scale HPC systems that will make it possible to address major societal challenges. As the goal defines an objective in functional terms rather than a solution, it is well suited to the procurement of R&D services and to the process defined in the PCP approach.
The key issues for this PCP will be:

- To define, from a practical procedure point of view, the implementation of the PCP approach best suited for HPC and to make it possible to realise the expected benefits of such an approach. This issue is of key importance for informing the potential future of PCP, possibly targeting large HPC system as part of the PRACE ecosystem.
- To define the technical goal mentioned above in the technical requirements.
- To make the best use of the limited amount of money available in order support a substantial and successful R&D activity. Compared with investments from DARPA, which have been at a level of hundreds of millions of dollars, will the investment of 10-20 million Euros across a number of suppliers actually influence and accelerate development.
- To commit to investment on a sustained timescale – two-year funding will be insufficient to achieve the objectives of technological innovation especially through a multi-phase approach.
- To attract the interest of European suppliers with the capability or capacity to potentially meet this need.

7. Key recommendations

- Requirements: know your requirements and understand how the market can best meet them. For example, take into account major trends like the fact that memory and memory bandwidths are increasingly lagging behind the CPU performance. Quantify required performance as accurately as possible on real or expected workloads.
- Recurrent versus capital: evaluate total lifetime costs in particular power consumption and the trade-off in terms of investment in advanced cooling and electrical supply systems (e.g. combined heating and cooling) versus ongoing running costs.
- Infrastructure: plan ahead – power densities within racks are increasing dramatically with the need to move to liquid cooling. This requires specialised mechanical and electrical cooling systems – typically a complete refurbishment of a machine room – with different systems working most optimally at different temperatures requiring different cooling loops.
- Market: timing is becoming more critical – continuously monitor supplier roadmaps to judge when is the best time to go to market and ensure competition.
- Software Development and Testing: invest ahead of the procurement in developing and adapting the software to run on the new systems. Seek access to prototype systems or software emulators and test and development systems during the operational phase to make sure that you can exploit the system once installed from day one and explore potential performance issues whilst not interrupting normal operations.
- Flexibility: identify phased delivery options as part of the procurement to potentially upgrade the system, bring in new technologies and take advantage of the vendors’ longer-term roadmap.

8. Conclusions

The PRACE project has provided us with a significant evidence base for what works and what does not work in terms of procurements. The key recommendations are captured above but the key conclusions are: know your requirements, know your infrastructure, know the market and plan ahead in terms of investing in software development, and make sure that the user community is ready to exploit the systems.

Acknowledgements

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