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Research Infrastructures

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[2] Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, High-Performance Computing: Europe's place in a Global Race, EC, http://ec.europa.eu/information_society/newsroom/cf/document.cfm?action=display&doc_id=891
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List of Acronyms and Abbreviations

AC	Access Committee
BoD	Board of Directors
BSC	Barcelona Supercomputing Center (Spain)
CEA	Comissariat à l'Energie Atomique et aux Energies Alternatives
CERN	European Organization of Nuclear Research
CINECA	Consorzio Interuniversitario, the largest Italian computing centre (Italy)
CINES	Centre Informatique National de l'Enseignement Supérieur (represented in PRACE by GENCI, France)
EC	European Commission
EEA	European Economic Area
EESI	European Exascale Software Initiative
EPSRC	The Engineering and Physical Sciences Research Council (UK)
ERA	European Research Area
ERIC	European Research Infrastructure Consortium
ESA	European Space Agency
ESFRI	European Strategy Forum on Research Infrastructures
ESRF	European Synchrotron Radiation Facility
ETHZ	Eidgenössische Technische Hochschule Zuerich, ETH Zurich (Switzerland)
EU	European Union
GDP	Gross Domestic Product
GEANT	Gigabit European Advanced Network Technology
GENCI	Grand Equipement National de Calcul Intensif (France)
HeC	High-end Computing
HM	Hosting Member
HPC	High Performance Computing
INCITE	Innovative and Novel Computational Impact on Theory and Experiment
IO	International Organization
NCSA	National Centre for Supercomputing Applications (Bulgaria)
n-HM	non-Hosting Member
NWO	Nederlandse Organisatie voor Wetenschappellijk Onderzoek…
OJEC	Official Journal of the European Community
PATC	PRACE Advanced Training Center
PCP	Pre-Commercial Procurement
PPP	Public-Praivate Partnership
PRACE	Partnership for Advanced Computing in Europe; Project Acronym
PRACE-1IP	PRACE1st Implementation Phase project
PRACE-2IP	PRACE 2nd Implementation Phase project
PRACE-3IP	PRACE 3rd Implementation Phase project
PRACE AISBL	PRACE Association International sans But Lucrative
PSNC	Poznan Supercomputing and Networking Center (Poland)
PPP	Public-Private Partnership
R&D	Research and Development
RI	Research Infrastructure
ROI	Return of Investment
SME	Small and Medium Enterprise
SSC	Scientific Steering Committee

TCO	Total Cost of Ownership. Includes the costs (personnel, power, cooling, maintenance, ...) in addition to the purchase cost of a system.
Tier-0	Denotes the apex of a conceptual pyramid of HPC systems. In this context the Supercomputing Research Infrastructure would host the Tier-0 systems; national or topical HPC centres would constitute Tier-1
US	United States
VAT	Value-Added Tax
WACC	Weighted Average Cost of Capital
WCSS	Wrocławskie Centrum Sieciowo-Superkomputerowe (represented in PRACE by PSNC, Poland)
WTOGPA	World Trade Organization Agreement on Government Procurement
XSEDE	Extreme Science and Engineering Discovery Environment

Executive Summary

This deliverable is the second of two deliverables on the evolution scenarios of the organisational and procurement model of the PRACE AISBL. The focus of this deliverable is on the models that might be implemented by PRACE in the near future. Its main objective is to serve as input to the discussion and decision in the AISBL Council on the future development of the Infrastructure. We analyse five possibilities for operational models by describing their relation to procurement models, the strategic principles of PRACE, and the challenge of transiting from the current model to a new model.

The five models to be considered are:

- Cycles Model
- Central Operator Model
- Operator Model
- Co-owned Operator Model
- Hybrid Model

In the first of the two deliverables an analysis of the current operation of the PRACE AISBL from the point of view of its legal environment, operation and services to users and internal approaches towards an integrated service was discussed. This serves as the basis for this deliverable in finding and choosing a suitable model for the evolution of the PRACE AISBL.

The first, part of this document is of interest for the future procurement of the machine(s) and considers which procurement model works best to maximize European industry engagement in HPC in relation to PRACE. We analyse the different models, namely competitive dialog, Pre-Commercial Procurement (PCP) and Public-Private Partnership (PPP).

In the second part, a set of high-level key drivers is introduced. The following key drivers are the main factors influencing the evolution of the operational model of PRACE:

- Meeting the mission of PRACE
- Goals and expectations of the PRACE RI members
- Goals and expectations of the user communities
- Goals and policies of the European Union and the European Commission
- Services to be delivered by PRACE AISBL in the future
- Assets of PRACE AISBL and its Members relevant to designing and delivering the services
- Legal issues
- Renewability

After describing each of the five potential operational models in terms of Tier-0 management, funding possibilities, services and ownership of the machine(s), we evaluate the models on lower-level strategic principles derived from the key drivers. These strategic principles are:

- Capability to reach PRACE AISBL technical and scientific objectives
- Capability to set up Governance
- Capability making use of available expertise
- Capability to raise funding for long term sustainability
- Capability to further pursue the objectives of building the ERA, or supporting ESFRI projects

This evaluation is summed up in a table which identifies the most problematic areas of each model.

In the third part of this document we analyse the transition from the current model to the new four models or the continuation of the current model. Important decisions need to be taken and the services of PRACE must remain available in this transition period to scientists and industry.

1. Introduction

In January 2008 and with support from the FP7 preparatory phase project, the PRACE initiative set up an ambitious plan for deploying a research infrastructure by the end of the project (in May 2010). The consortium succeeded in:

- Agreeing on the location of the legal seat for PRACE;
- Defining the legal form of the RI;
- Defining the governance structure;
- Specifying funding and usage strategies for the initial period;
- Establishing the peer-review process;
- Establishing links with the HPC Ecosystem;
- Developing the Operation Model for the initial period;
- Setting up and providing technical services for PRACE, such as user support and training and HPC technology assessment and guidance.

As a result, the PRACE RI was inaugurated on the 23rd April 2010 and started its operation using the Cycles model defined during the preparatory phase project.

PRACE RI Inaugural Meeting, Barcelona 9th June 2010

This process worked to align the different perspectives of the members by having a five years agreement for operating, funding and growing up the research infrastructure. During these five years, it was planned that the PRACE consortium would work together to reconsider the operational model and eventually develop one that better meets the needs of all partners. This deliverable plays a part in that process which has recently been triggered through an AISBL strategy workshop on May 15. It is expected to be completed in 2013, two years before the end of the initial five year period.

The relevance of having a pan-European Research Infrastructure for supercomputing was initially manifested with the results of the scientific cases conducted back in 2006, and this was acknowledged having PRACE in the European Roadmap for Research Infrastructures. The impact that was foreseen is framed in the following topics:

- strategic competitiveness;
- attractiveness for researchers;
- scientific excellence;
- support to industrial developments.

In addition to these, PRACE was conceived as a solution for the fragmentation of computational resources in Europe and to achieve a competitive position on the European HPC industry and on HPC capabilities of its resources versus other continents.

During its time of operation, PRACE has been performing its mission and building up an operative structure that evolves continuously into a more autonomous organization. Although this operating structure is a proven success, it has a limited duration of five years (ending up in 2015) and PRACE needs to consider the appropriate transition to continue accomplishing its mission beyond 2015. The models to examine should consider different scenarios including different degrees of support from the European Commission as well as other relevant dimensions that are described in the next chapters of this document.

The specific support that PRACE can receive from Europe is not yet fully defined, however, the strategic importance of HPC in Europe has been recently subscribed through a communication to the European Parliament, The European Economic and Social Committee and the Committee of the Regions public. This newly released communication highlights the strategic nature of HPC as a crucial asset for the EU's innovation capacity calling on Member States, industry and the scientific communities, in cooperation with the Commission, to step up joint efforts to ensure European leadership in the supply and use of HPC systems and services by 2020. This communication follows the Communication on ICT Infrastructures for e-Science and the conclusions of the Council asking for "further development of computing infrastructures such as PRACE" and to pool "investments in HPC under PRACE, in order to strengthen the position of European industry and academia in the use, development and manufacturing of advanced computing products, services and technologies".

At this point in time, PRACE RI has not taken any decision towards its future operational model. This document aims to provide research material for the consideration of the PRACE Council when discussing the evolution of PRACE. It is important to note that the options identified and analysed in the document, do not reflect an agreed position of the PRACE Council and just report the analytical work within the project. These results are therefore oriented to feed relevant material and proposals to the discussions that are taken place by the governing bodies. This represents a deviation from the original plan described in D2.2.1 [3] where the creation of a mirror political group was foreseen. The perspective at this point in time was not clear enough as to involve political represents of the interested countries to decide on specific models, although there have been different informal contacts that have influenced the process in different ways.

The remainder of this document is structured in the following way: Chapter 2 describes a set of potential procurement models for PRACE that the different operational models might integrate. Chapter 3 contains the analysis of the operational models for PRACE. It first analyses a set of common set of key drivers that will influence the evolution of the current model. Taking these elements into consideration, subsection 3.2 shows a

classification of different potential models according to 1) the amount of systems managed by PRACE, 2) the assets of the association (cycles, machines or both) and 3) the shared ownership where applicable. Only the options assessed as viable are represented and analysed. Each model is described in terms of a common set of elements (section 3.3). Section 3.4 makes an assessment of each model against a set of previously defined strategic principles identified in D2.2.1 [3] and D2.3.2. [4] The identified models are analysed in section 3.5 from the perspective of the transition from the current operating model, identifying the most important challenges and factors to be considered upon a potential transition in 2015. Finally Section 4 wraps up the analysis highlighting the most relevant findings.

2. Potential Procurement Models

Procurement is key for any operational model. In this section we aim at providing analysis of the available options to assess how it could affect procurement to the organisation.

Procurement procedures conducted by entities from the public sector are governed by the "Directive 2004/18/EC of the European Parliament and of the Council of 31 March 2004 on the coordination of procedures for the award of public works contracts, public supply contracts and public service contracts" which derives from the "Agreement on Government Procurement" of the World Trade Organization.

In the current funding model and very likely in whatever possible evolution of the funding scenario (see D2.3.2), entities conducting the procurements belong to the public sector; therefore the directive mentioned above, complemented by its implementation in the national regulation applicable to the entity, is considered.

The directive defines:

- a large set of possible procedures for procurements,
- several cases of exemptions for which procurements can be conducted without following the procedures defined in the directive.

In this context, we are focusing in this chapter on a limited set of procurement procedures or approaches that are of specific interest for HPC. These procedures or approaches are well suited to procurement of complex systems that are typical of high-end supercomputing where systems procured are the first or among the first of a kind, possibly involving R&D and technical exchanges between the supplier and the procurer. Considering this situation, it is very important to take risks into account, through a risk management system including risk mitigation measures and through a possible sharing of the risks between the supplier and the procurers.

The list of considered procedures is the following:

1. The competitive dialog (as defined in the directive, article 29) which is widely used for procuring supercomputers or other IT equipment.
2. The pre-commercial procurement (PCP) which is an approach proposed by the Commission for fostering innovation in Europe and that is based on the exemption of the directive (article 16, (f)). Therefore, in this case, the procurement procedure is formally undefined and needs to be defined by the procurer.
3. The procurement procedure (using, for the specific purpose, one of the procedures defined in the directive – possibly a competitive dialog), for establishing a Public-Private Partnership (PPP).

Whatever object is bought, especially in the case of a supercomputer, financing can be organised in several ways. Buying the equipment and paying its cost at the beginning is often used but there is another option, frequently used by industrial customers: renting or leasing systems, possibly including some upgrades. This option not only smoothes the payment schedule, by substituting yearly payments to a single initial one, but also avoids the procuring body to own the systems, which can have some legal advantages for PRACE. In principle, this option can be applied to any procurement model. Further analysis, both financial and legal, of this possibility is advised in order to understand its major consequences and to perhaps be considered as viable in the future.

Finally, it is worth noting that so far no relationship has been identified between the operational models and the kind of procurement procedures that can be used; this means that any procurement procedures is likely to be usable regardless of the operational model.

2.1. Competitive dialog

Based on the experience of PRACE partners, gathered by PRACE-1IP/WP8 and documented in deliverables produced by this work package, the competitive dialog is the preferred procedure for procuring their own IT equipment or services.

Before 2004, the only two public procurement procedures available were the open procedure and the restricted procedure. Both procedures require that the procuring authority publishes all technical criteria and the awarding procedure when issuing the call for tender, i.e. up-front. The restricted procedure differs from the open procedure only in the point that it starts with a pre-qualification phase which allows to pre-select the number of bidders. For supercomputer procurements, both procedures are sub-optimal because they assume the procurement of a standard product based on available technologies at the time of issuing the call for tender and they assume a-priori definition of detailed technical criteria whereas for a supercomputer functional requirements, leaving open various technical solutions is desirable.

In order to improve the procedure for procurement of items for which specifications cannot be defined sufficiently, the European Commission introduced, in April 2004, the competitive dialogue procedure (Directive 2004/18/EC).

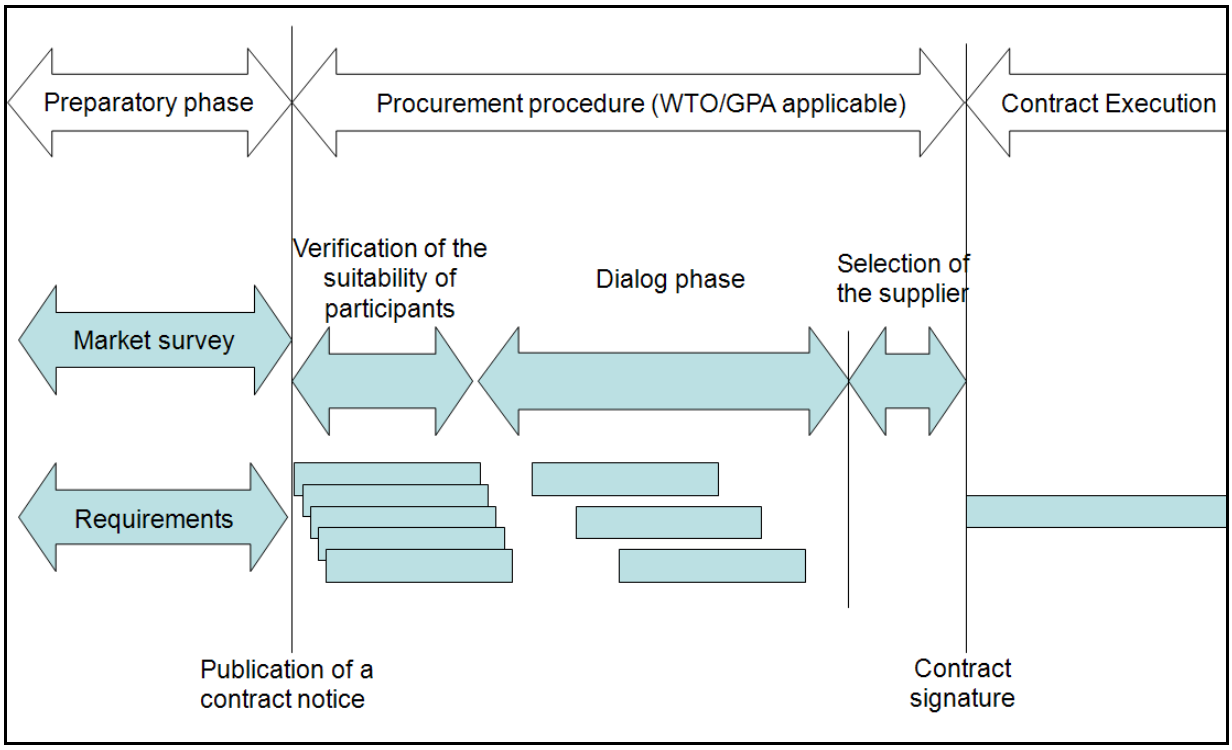

Figure 1: Schematic view of the competitive dialog procurement process

The preparation of a competitive dialog usually involves gathering requirements and constraints and understanding, through a market survey, what is to be expected from the market in order to draft the procurement documents (including the specifications expressed in a functional manner). The competitive dialog itself is usually implemented in several phases, schematized in Fig. 1 :

1. Publication of the contract announcement, usually using the supplement of the OJEC.
2. Pre-qualification phase (verification of the suitability of the participants), like in the restricted procedure, in order to select the suppliers that will be involved in the dialog phase.
3. Dialog phase, usually consisting in a set of meetings organized with the objective of finding the best solutions to fulfil the requirements. This discussion can be repeated and refined solutions are received. The dialogue phase ends when the procuring party has the feeling that the potential solutions have been defined well enough.
4. Selection of the supplier based on final offers that are submitted at the end of the dialog phase.

The most important and fruitful part of the competitive dialog is the dialog phase. Intermediate offers are usually provided during this phase, providing the input for the meetings.

The usage of competitive dialog for procuring R&D prior to acquiring a large scale supercomputer has been reported by PRACE partners. Such R&D was needed to meet the requirement of the procurer prior to procuring the full system. The full system implemented the result of the R&D phase, based on a contract in which the procurement of the supercomputer was optional and conditioned by the result of the R&D.

2.2. 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.

Since then, the approach has gained a lot of momentum and several successful implementations have been reported although none of these are for HPC. PCP is available as a mean to procure innovative R&D for achieving specific technology and system targets. In addition, PCP attracts stronger attention at EU level leading to a conclusion that within the EU, only very few public procurement budgets are devoted to R&D through PCP, in comparison to the US [6]. Furthermore, it can be seen that in US PCP is used to advance the state-of-the-art of HPC. [2]

A PCP aims at conducting R&D up to the development of a limited volume of first products/services in the form of a test series. In the field of HPC the target can typically be a solution to a major technical challenge. The R&D is organized in several phases, schematized in Fig. 2:

- Solution exploration leading to solution design;
- Prototyping;
- Original development of a limited volume of first products/services.

The number of suppliers decreases from one phase to the next in order to select the suppliers that best address the technical challenge on which the PCP is based.

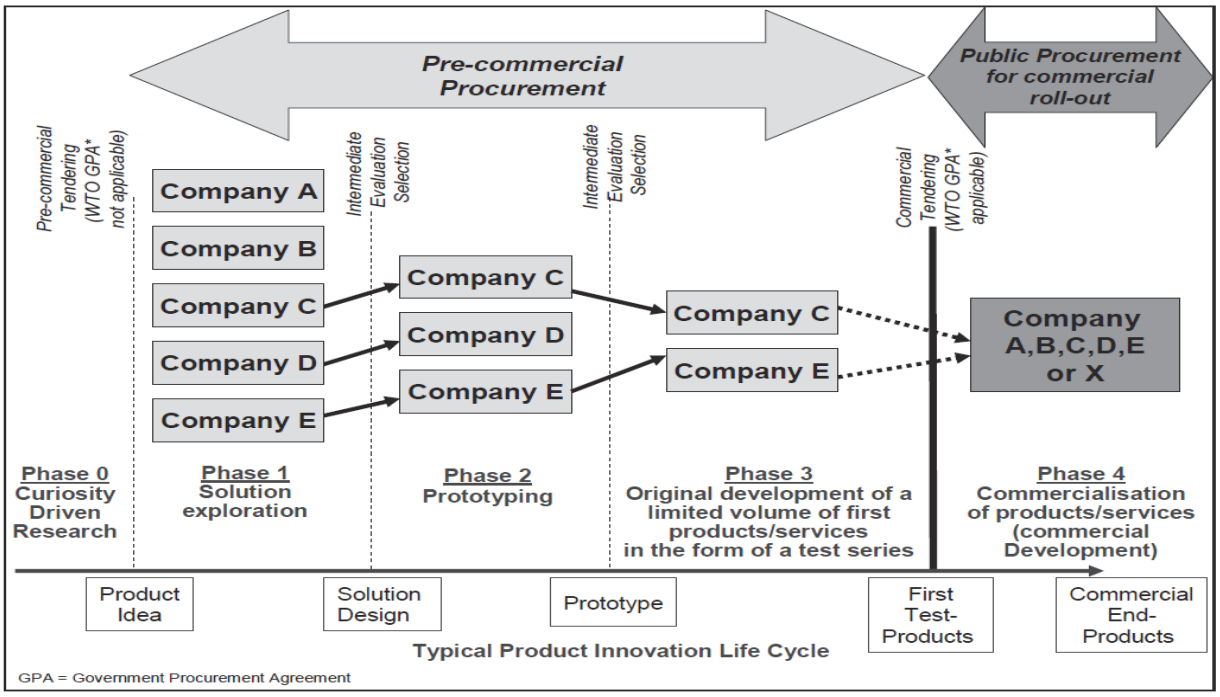

Figure 2: Schematic view of the PCP phases

Within the EU the majority of high-end HPC systems are procured by the public sector [2]. Using PCP[1] could provide the HPC ecosystem with an exciting opportunity to drive forward

[1] PRACE 1IP project Work Package 8 has produced documentation on PCP, for instance D8.3 contains a section on PCP that gives detailed background on this approach and makes suggestions about its usage in the HPC domain; it lists key issues to be addressed by a possible future PCP within PRACE 3IP including defining the

the development of innovation for HPC systems tailored to meet European requirements and aimed at solving major societal challenges by:

- pooling the efforts of multiple procurers – through joint PCP since shared R&D effort will likely be beneficial to all organization using HPC;
- stimulating indigenous supply through "locating relevant portions of the R&D and operational activities related to the PCP … in the EEA";
- encouraging procurers to act over the mid-to-long term to define solution requirements for the required public sector innovation.

rom a procurement procedure point of view, the PCP falls inside the specific exclusion of the directive mentioned above, chapter 2 (Article 16 (f) : "research and development services other than those where the benefits accrue exclusively to the contracting authority for its use in the conduct of its own affairs, on condition that the service provided is wholly remunerated by the contracting authority." ("WTO GPA not applicable").

In order to fall inside this exclusion, the PCP has the following key elements:

- It is for R&D services only: R&D activities >50 % of the overall budget
- The application of risk-benefit sharing: shared IPR. The public purchase does not reserve the R&D results exclusively for its own use[2]
- A competitive procurement designed to exclude state aid: The PCP R&D work has to be done by marked prices in order to ensure that "the service provided is wholly remunerated by the contracting authority".

Just like a competitive dialogue, before a bid for a PCP it can be useful to conduct a preparatory open dialog since it is necessary to inform well in advance the potential suppliers about the process and possibly collecting their feedback. It is necessary to understand what is commercially available (or what will soon be commercially available) compared to what is desirable for future systems.

Concerning PRACE, it is planned to investigate the PCP approach with a pilot joint PCP in the PRACE-3IP project. This exercise will target "Whole System Design for Energy Efficient HPC" and will be supported by a set of partners of the project. Investigations will be conducted in order to take into account tax issues such as the consequences on the status of the contributions to PRACE regarding national laws.

On a longer term, despite the fact that the final parameters of the next framework period are still not adopted opportunities for PCP actions for HPC R&D at EU level engaging strongly PRACE can be defined. In future, PCP could become eligible for Union co-funding (e.g. via Horizon 2020 – e-Infrastructures; cohesion policy instruments)[3] by following the scheme: Joint PCP actions involving several or all Member States (e.g. organised through PRACE) for developing leadership-class HPC capabilities with a clear European mission.[4].

In conclusion, PCP is a tool for stimulating R&D which is needed to create innovation for HPC in Europe on the way to the new Tier-0 systems in the exaflops range. In this way PRACE should have the possibility to provide the best Tier-0 system for European users

procurement procedures, making the best use of available money, attracting the attention of potential suppliers and understanding the necessity of a long term effort.

[2] Example shared IPR: Public purchaser grants IPR to company; in the case the company does not use the IPR in a certain period, the public purchaser can give the IPR to a different company. In addition the public procurer should insist in terms of references, which open the IPR to other companies under fair conditions / reasonable.

[3] Within the limits of the budget allocated in the programme for that purpose. Subject to the adoption of the Horizon 2020 Programme by the Legislative Authority.

[4] COM(2012) 45 final: High-Performance Computing: Europe's place in a Global Race, Brussels, 15.2.2012

through a mix of procurement of commercially available systems and of pre-commercial systems.

2.3. Public-Private Partnership

Public-Private Partnership (PPP) was introduced in the early 1990s - at first in UK. It has attracted a strong interest since it gives the possibility of bringing in new sources of financing for infrastructures and services. Primarily, PPP is seen as an instrument for economic development in a variety of sectors, including business, infrastructure development, technology, tourism, and the environment.

Typically, a PPP consists of a contract between a public sector entity and a private party, in which the private party provides a public service or project and assumes substantial financial, technical and operational risk in the project. An essential part of the implemented PPP model is the well-defined structure of PPP contracts, monitoring of the project management and development, and reviewing and evaluating of the projects' success.

Some recent examples were reported in which the costs for the public sector entity and/or for the end users were not as good as expected, based on the supposed higher efficiency of the private sector. This means that a careful analysis of the costs must be conducted before deciding whether a PPP is appropriate.

Despite all constraints such as lack of legislation basis at EU level and in the majority of European countries, two basic PPP models can be predefined. They need to be considered as possible future options for the deployment of PPP as part of the European HPC Eco-system:

- EU level: A form of PPP such as Joint Technology Initiatives in these technology areas where EU has competitive advantages;
- Regional level: Creation of regional HPC clusters including government, industry and research/HPC representatives from more than three countries in combinations among these legal entities for the next activities:
    - Management of HPC sites and execution of HPC-related projects;
    - HPC modernization and extension of existing hardware, software and applications;
    - Definition of strategic priorities and promotion of the relationship: research – product/services.

In the two conceptual PPP models above, it is crucial to define sound criteria for monitoring the on-going activities and for evaluating the overall success in both directions: detecting the discovery of new fundamental knowledge and spurring practical innovations.

Generally speaking, in the domain of HPC, especially in the context of providing resources for academic and public research, a PPP may not be a very attractive solution, due to the complexity of the involved procedures compared to the investment amount and the short time span. Another issue is represented by the calculation of the risk that private party could assume (if any), compared to the weighted average cost of capital (WACC).

3. Potential Operational Models

3.1. Key drivers influencing the possible evolution scenarios

The selection of the operational model that PRACE will adopt once the initial period will finish is influenced by different factors. In D2.2.1 these factors were categorised into a set of strategic principles that captured requirements and constraints for the evolution of the PRACE operational models. From a higher level perspective, there are a set of factors that stem from the named strategic principles that are considered the most important ones influencing the evaluation of the models. These factors are referred to as key drivers and are described as follows:

3.1.1. Meeting the mission of PRACE

A critical aspect of any model is that it must be able to ensure that PRACE meets its mission as stated in the following excerpt from the Statutes of the Association PRACE AISBL [1]:

"....

a) to develop and provide an Infrastructure at European level which allows the scientific communities, including those within industry, to access European High-end Computing systems;

b) the management of the coordination between the Infrastructure and existing national computing centres (Tier-1) and also, if agreed, regional computation centres (Tier-2), to allow for the establishment of relationships with the HeC user communities; and

c) the provision and rationalization of access to the Infrastructure by qualified European and international scientific communities, either academic or industrial, whose projects may be evaluated for such purpose.

…"

This is a fundamental principle, without which an operational model cannot be accepted. In D2.3.2, the "loosely-coupled without central system" model was rated as not meeting the mission of PRACE because it doesn't ensure leadership computing. This is the reason it has been discarded in the models analysed in this document. Consistently, in the five models presented below, none of them is inherently contradicting the mission. However some models might make it more easy for PRACE to fulfil its mission and this has to influence the decision on the model to be chosen.

3.1.2. Goals and expectations of the PRACE RI Members

One of the reasons PRACE was created is because HPC is a domain where sharing, both resources and knowledge, is becoming not only fruitful but somehow needed. Growing complexity and costs of Tier-0 machines, as well as strong investments from other regions of the world (especially US, Japan, China and India), made it important to pool the available resources in Europe in a common structure and give incentives to grow beyond what is possible in any country alone.

Leadership computing has become so important to competitiveness, for academic research and industry, and in the meantime so expensive and complicated, that European countries gathered in PRACE. Collaboration between countries with different areas of expertise is one

of the key factors that made PRACE successful: over the course of few years, it managed to give extensive access on supercomputers of different architectures to the best projects in all the scientific fields.

As a pan-European infrastructure, PRACE allows its partners to gain worldwide visibility, drives researchers to take advantage of the best available systems, and fosters industrial competitiveness. It centrally manages a peer-review process for which the assessment panel is composed of independent, internationally-recognized experts and encourages the best science within every scientific community.

This dimension of collaboration, between different kinds of expertise and between different cultures, is essential and will remain as the backbone to support PRACE's goal: providing access on the best systems to the best scientific projects.

In order to keep collaborating, it is important to be able to transparently assess how each member benefited from PRACE. There are two types of members in PRACE: Hosting Members (HMs), who agreed to commit an equivalent of 100 million Euro on a 5 years timespan, and non-Hosting Members (n-HMs) who currently pay a fixed fee of 60 000 Euro each year.

With the initial period coming to an end in 2015, the major contributors to PRACE want to assess what they received in return for their investment. It is especially crucial at a time when, in each country, the case for further investment in HPC will have to be made to renew the funding. An analysis of the *juste retour* principle, not yet implemented in PRACE, is highly desired. To implement such a mechanism, there is no solution broadly accepted in Europe. Each organization has its own way to enforce *juste retour* based on its own operational model.

For the particular case of PRACE, D2.3.2 identified the set of elements that can create an unbalanced financing situation to be considered in the analysis of the *juste retour* concept. The most relevant elements identified are:

- in the Operator model, Hosting Members may have to provide a hosting environment that includes operation and support staff, maintenance services, and hosting infrastructures (this may be paid for by the member hosting the system);
- in the Cycles model, Hosting Members, in addition, would have to procure and pay for the systems;
- between different Hosting Members operating costs may be different.

It is clear that depending on the investment in the infrastructure, Hosting Members would have to have different benefits in order to level the Return of Investment (ROI) amongst the members to ensure the sustainability of the model.

An example of *juste retour* implementation is the usage quota mechanism that is being successfully applied in other Research infrastructures such as ESRF.

If we were to use a quota mechanism in an operator operational model (Cash Financing Model), the distributed payment of the procurement and/or operating cost from each member would be proportional to the usage of the system and the investment made.

For the cycles operational model (In-Kind Financing Model [4]), since the most significant contributions are made in-kind, these should be evaluated and mapped to an economic cost. This way partners with higher levels of investment (directly into the infrastructure or indirectly in the provision of Tier-0 systems) would benefit from higher quotas of usage.

Having a *juste retour* policy in place is indeed a key driver for the future operational model for PRACE. The future PRACE Operational model will have to have clear mechanisms to avoid an excess of "free-riding" on PRACE resources and return of investment for the

members with higher level of contribution. The design of the *juste retour* mechanism should encompass measures to tackle these two points, and it will have to have a precise definition of what is considered as an excess of free-riding and also a precise definition of the nature and level of return of the contributors expected from their investments.

3.1.3. Goals and expectations of the user communities

Users are integral to the success of PRACE. The operational model that PRACE will adopt in the future should be developed to ensure that users are provided with an excellent service to enable them to carry out world-leading research.

Contact and exchange with the end users of the resources provided by PRACE is taking place. The Scientific Steering Committee is the body of the PRACE AISBL implemented to be the link between the scientific community and the research infrastructure. Composed of prominent scientists, their role is to give strategic advice to PRACE on the important issues affecting the scientific community, and to gather its needs and expectations.

The User Forum is dedicated to gather operational-level needs coming from the researchers effectively using the resources, e.g. researchers whose projects have been awarded resources by the PRACE peer-review process.

The main expectation of the user communities is to be able to benefit from world-leading systems to run their very resource-consuming projects. But different fields and different projects have diverse requirements regarding the type of HPC resources to use, not only on the amount of computational power but also on the architectures that their codes use. In this respect, operational models that make available to European science different architectures will be serving better the European scientific communities compared to models where just a single system is made available.

In order for the European scientific communities to stay on top of competitiveness, PRACE also has to always provide high capability systems, in the same way other regions of the world are doing. To do that, PRACE must adopt a model where the joint effort from the members leads to a permanent deployment of continuously more powerful systems to support European science.

User communities expect long-term sustainability and reliability from PRACE. It is vital for PRACE to be trustworthy in its commitment to provide the expected services in a sustainable way, because it will drive the scientific communities to align their HPC strategy according to those services. Without confidence in PRACE's ability to fulfil its mission for a long time, there is a risk that the resources will not be used at its best.

3.1.4. Goals and policies of the European Union and the European Commission

The EC has a major interest in the PRACE AISBL, because almost all scientific fields need top-class computer resources to solve the most challenging problems. So far the EC has supported the implementation of PRACE AISBL through funded FP7 projects. It has not yet decided on its possible direct contribution to the funding of the PRACE AISBL, and therefore on participation in the acquisition and operation of computing resources made available to users through the PRACE AISBL. Nevertheless, the EC has recently issued, February 15th 2012, a public communication [2] re-affirming its interest in HPC ("HPC is vital for the EU's industrial capabilities as well as for its citizens") and in particular its support to PRACE: "The Commission will continue to support PRACE and ensure it remains an integral part of the

European e-Infrastructure; and it will provide support for establishing and operating a European e-Infrastructure for HPC".

This communication, after praising PRACE achievements in its few years of existence, asks for a further development through specific objectives:

"Following the creation of the PRACE legal entity in 2010, the academic sector is pooling its leadership-class computing systems as a single infrastructure and makes them available to all researchers in the EU. Critical mass is achieved and access to these top-of-the-range HPC systems is provided on the basis of scientific excellence rather than the geographical location of a researcher. PRACE is further extending its services to mid-range HPC systems with the objective of providing a distributed computing platform that serves its users irrespective of their location and the availability of national resources. The PRACE model of pooling and sharing systems and expertise makes optimal use of the limited resources available.

The Council of the EU asked for a further development of the European High Performance Computing Infrastructure and a pooling of national investments in HPC in order to strengthen the position of European industry and academia in the use, development and manufacturing of advanced computing products, services and technologies. This is the high-level objective driving a renewed European HPC strategy.

To realize this general objective, the following specific objectives have been identified:

- provide a world-class European HPC infrastructure, benefitting a broad range of academic and industry users, and especially SMEs, including a workforce well trained in HPC;
- ensure independent access to HPC technologies, systems and services for the EU;
- establish a pan-European HPC governance scheme to pool enlarged resources and increase efficiency including through the strategic use of joint and pre-commercial procurement;
- ensure the EU's position as a global actor."

In the conclusion of this communication it is stated that "with the setting up of the European Space Agency (ESA) in 1975, Europe decided that independent access to space was a strategic goal that was essential for Europe's competitiveness. This Communication advocates a similar strategic decision for HPC systems and services that are essential for the EU's social, economic and scientific development and its competitiveness."

The reference to ESA makes it clear that the level and nature of contribution of the EC to PRACE is likely to be influenced by the operational model chosen by PRACE. The EC usually supports directly (not through implementation projects) existing infrastructures that are of strategic importance and organized in an appropriate and sustainable way (International Organizations, ERIC), such as ESA and CERN. For this kind of support, EC funding is usually below 20% of the total running cost of the research infrastructure. An exception is GEANT, for which a continuous project funding scheme is used to allow for an EC contribution of 50% of the running costs.

Hence, the position of the EC on the different operational models, although not clearly stated at that time, is a key driver influencing the decision. As in the case of other Research Infrastructures, PRACE expects the support of the Commission in order to make the identified models economically robust and sustainable.

3.1.5. Services to be delivered by PRACE AISBL in the future

PRACE already delivers a set of core services. As part of its mission, it provides access to world-class HPC resources, for both academia and industry, and allocates those resources through a peer-review process independently evaluating scientific excellence of the applying projects.

As part of the work planned in the FP7-funded implementation projects (PRACE-1IP to PRACE-3IP), it provides training to potential users through recently awarded PRACE Advanced Training Centers (PATC). Technical and scientific support, for instance through code enabling and scaling, are also in the scope of PRACE's activities.

These core services must be further strengthened by the next operational model of PRACE.

Additionally, one can imagine other services that PRACE might be able to deliver in the future. Especially, as indicated in the recent EC communication, PRACE can put in place "an e-Infrastructure for HPC application software and tools" so that it ensures the availability of quality HPC software to users.

PRACE can also establish "centers of excellence for the application of HPC in scientific or industrial domains that are most important for Europe (e.g. in the area of energy, lifesciences and climate)" and "hardware and software co-design centers […] to focus on the advancement of technologies, HPC resources, tools and methodologies".

The types of services to be delivered by PRACE, as well as the quality with which they are delivered, must be in accordance with the possibilities of each of the operational models.

3.1.6. Assets of PRACE AISBL and its Members relevant to designing and delivering the services

PRACE is a partnership, and therefore has not emerged from scratch. It is supported by existing infrastructures and related staff from individual partners. National computing and research centres usually have experience in all the aspects of HPC: procurement and operation of systems, scientific expertise, support of potential applications, networks with scientific communities, etc.

The ability to take advantage of the individual capabilities and competences of each partner is a major driver without which PRACE is bound to be under-efficient. If PRACE procures and operates its own systems, it might be useful to take advantage of the assets of its members. In particular, PRACE can consider using available facilities and can train existing staff to deliver the foreseen services where this would meet the scientific research community's needs.

Ideally, these capabilities not only have to be exploited by PRACE, they must be consolidated and multiplied by their interaction within PRACE. The operational model to be chosen has to fully leverage this collaboration of different areas of expertise, including some possible contribution from the EC.

Apart from the assets of its individual members, PRACE has developed assets of its own. The headquarters in Brussels and its dedicated staff have to be strengthened in the next phase of the association. It is very important to be able to capitalize on what PRACE already achieved, meaning the creation and the work of bodies such as the Board of Directors, the Scientific Steering Committee, the Access Committee and the User Forum. Successful initiatives coming from the implementation projects, such as the industrial seminars, have to be continued and reinforced by PRACE. When deciding over the future operational models of

PRACE, the decision-makers will have to take all these points into consideration to ensure consistency and capability to further develop the partnership.

3.1.7. Legal issues

Any model must fit within a legal framework and be enforceable. The legal form each model lies upon has many implications, such as the nature of the members. In International Organizations (IOs) for instance, members are countries (and not entities representing them as currently the case). This can lead to easier contribution from the EC, but at a price of lengthy negotiations to get strong commitments from the members.

In D2.3.2, we analysed pros and cons of three kinds of options for legal forms: International Organisations and ERIC, International entities under a specific national law, and non-European programs.

The model should try as much as possible to foresee the implications resulting from the different tax models used in the partners' countries. Depending on the model, it is also necessary that remote centres and stakeholders are included under the legal umbrella.

The presently used Belgian AISBL legal form allows only for limited, marginal commercial activities. VAT and taxation are strong constraints too. Members' national tax and VAT laws are further constraints for models that include the possibility of charging for services.

The consideration of some of the models identified in this deliverable should involve an in-depth legal analysis from all the potential members of PRACE, since elements like co-funding, joint ownership, long term commitment of funds or provision of services to industry may have legal barriers for some of the members.

3.1.8. Renewability

It is important to recall that PRACE has a peculiar model. Unlike CERN and ESRF for instance, where the main funding consists in building the facility and upgrading it every 10 years or so, Tier-0 machines need to be replaced every 3 years in order to keep up with the pace of leadership computing, which means that PRACE needs continuous funding from the members. The need to renew the systems should not impact the long-term sustainability of PRACE.

Renewability is intrinsic to fulfilling PRACE's mission to ensure competitiveness of resources available for the European scientists. This is a continuous mission that needs permanent planning of the next step to make sure to always be ahead of the necessary adjustments.

The operational model should be designed with the renewability concept in mind, hence models that encompass the financial support at a European level with direct co-funding of infrastructures would ease the renewability and would be preferred.

3.2. Classification of potential future operational models

A set of potential operational models has been identified, taking as basis the research done in the previous deliverable D2.2.1 [3]. Several points of difference were considered for the models and the basic features were identified, which indicate the main possibilities for operations. The outcome matrix, shown in Table 1, is based on three dimensions: the number of Tier-0 systems available in the PRACE infrastructure, the type of assets owned by PRACE and the shared ownership.

	Single System	Multiple Systems
Cycle	-	Cycles
Machine	Central Operator	Operator/Co-owned Operator
Both	-	Hybrid

Table 1 : Classification of potential future operational models

The first dimension of the matrix – number of systems – consists of two options: Single System and Multiple Systems. It appears that the exact number of multiple systems is not relevant from the point of view of operational model, thus this option assumes two or more.

The second dimension of the matrix indicates the type of assets owned by PRACE. It consists of three options: cycle, machine and both. The cycle option means that the members of PRACE give the cycles of their own machines to be allocated by PRACE. The machine option indicates the ownership of resources by PRACE. The third option assumes that there are both cycles and whole machines at PRACE disposal.

The third dimension – shared ownership – is not applicable in each case. The options, which have been assessed as not viable, have not been considered any further. This includes the funding for a machine or a part of it in a case it is to be owned by other institution.

The loosely-coupled models introduced in the funding scenarios described in D2.3.2 [4] are not considered here, since they do not meet the mission of PRACE. It would be very difficult to gain a required level of sustainability, both from the organizational and financial point of view, in a distributed organization operating in such models. Thus, based on the proposed classification we consider five models as valuable for further analysis: Cycles, Central Operator, Operator, Co-owned Operator, and Hybrid.

3.3. Characteristic of potential future models

3.3.1. Introduction

The previous section shows the classification of five models of relevance for PRACE. They have been classified according to three major dimensions: the amount of systems managed by PRACE, the type of assets owned by the association (cycles, machines or both) and the shared ownership (where applicable). In the following subsections the identified models are analysed in terms of the distribution of responsibilities of other aspects such as Tier-0 management, ownership of assets, management responsibilities of services, provisioning of Tier-0 system operation, and model of contributions for funding the infrastructure.

Aside from the differentiating factors of the identified models, all the models have two of the PRACE core services in common: the peer-review process for allocating core hours to scientific projects based on scientific excellence, centrally managed by PRACE, and the training and dissemination activities coordinated centrally by PRACE.

3.3.2. Cycles Model

	Single System	Multiple Systems
Cycle	-	**Cycles**
Machine	Central Operator	Operator/Co-owned Operator
Both	-	Hybrid

Table 2 : Position of the cycles model

The Cycles model, highlighted in Table 2 and schematically described in Fig. 3, is referred to as the In-kind financing model in D2.3.2 [4]. It is the current operating model governed until 2015 by the Agreement for the Initial Period and the PRACE AISBL statutes. Under this model, each Tier-0 system is funded, owned and operated by the hosting state (Hosting Member –HM) at their national facilities. All the procurement and operating costs are also covered by the Hosting Members.

The deployment plan of Tier-0 systems at the European level is discussed and coordinated centrally (PRACE AISBL can issue some guidelines) but a Hosting Member can deviate from this plan for good reason and thus has the final word on its procurement process, including full power to choose whichever architecture it prefers. A percentage of the amount of cycles that the machine provides is committed to PRACE, and the rest can be used nationally without any interference from the PRACE AISBL. The only requirement is that the Total Cost of Ownership (TCO) of all the cycles contributed by each hosting country equals a certain amount to be decided by the Council. Currently, under the Agreement for the Initial Period, each Hosting Member has to commit a contribution equivalent to 100 million Euros and provide it to PRACE within a 5 year timeframe.

On top of the cycles committed by the HMs, all the PRACE members (HMs and non-Hosting Members n-HM) pay a fixed fee to the PRACE AISBL. Under the current model, the EC contributes through FP7-funded preparatory and implementation projects that are meant to support the activity of the central organization within the timeframe of duration of the project.

The Cycles model currently in operation does not implement any specific measure to ensure *juste retour,* however the model could integrate a specific mechanism to somehow link the level of contribution to the level of usage. The current model could accommodate a different scheme of co-funding with the EC, including direct cash fees to the association, or co-funding of operation of systems in order to relieve the financial weight on the members and in particular on the HMs and also to ease the implementation of a *juste retour* mechanism.

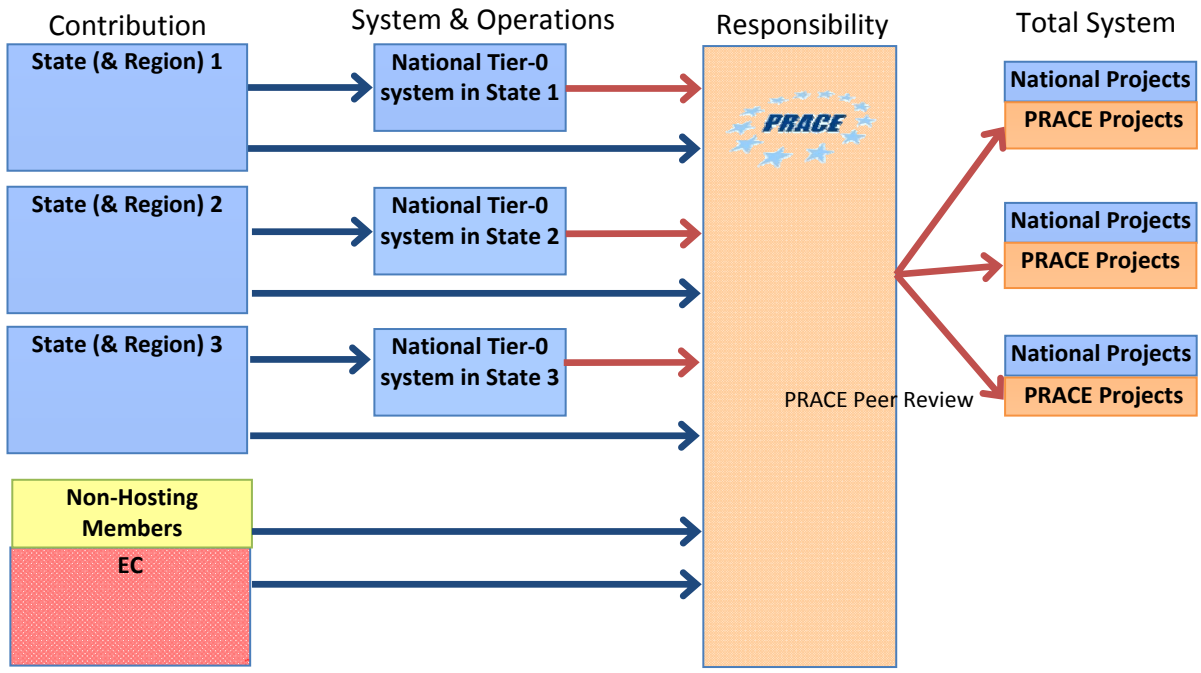

Figure 3: Cycles Model

3.3.3. Central Operator Model

	Single System	Multiple Systems
Cycle	-	Cycles
Machine	**Central Operator**	Operator/Co-owned Operator
Both	-	Hybrid

Table 3 : Position of the central operator model

This model, highlighted in Table 3 and schematically described in Fig. 4, has previously been identified for funding model analysis in the deliverable D2.3.2 [4]. The Central Operator Model is characterized by having one single Tier-0 system that is owned and funded by PRACE. The procurement process is conducted by PRACE employees. The entire system belongs to PRACE, who allocates the vast majority of the cycles through peer-review. The TCO of the system is fully covered by PRACE (facility, operating staff, maintenance and electricity).

The location of the system is an important factor that can define different scenarios. In this respect two cases are clearly differentiated: the system is operated in an existing national infrastructure or the system is operated in a new facility.

If the system is deployed in a new facility, the personnel will need to be newly recruited, but if the system is deployed in existing facilities of some Member, the system can be operated using existing staff from the Hosting Partner.
The case where the system is deployed in an existing national infrastructure requires an agreement on the precise terms of the relationship, including how it affects the contribution of the HM to PRACE. One the one hand, if any work for PRACE is done by people employed by their countries, it could count as an in-kind contribution to PRACE. On the other hand, the

location of the PRACE system in a Member's country would benefit this member in various ways [4]: employing national personnel, raising reputation, direct dissemination, impact in their scientific communities and society in general, consumption of services and related payment of national taxes (electricity, facilities, personnel, etc).

The deployment policy of PRACE under this model is another important factor where two different scenarios can be identified: having a permanent location for the PRACE infrastructure or having a rotatory deployment in different Members facilities. The design of a general deployment plan and the selection of the hosting places will have to be carefully designed respecting the different degrees of investments and the technical advantages for the different options.

The associated funding model foresees substantial contribution from the EC since it encompasses a centrally owned Tier-0 system whose resources are distributed according to scientific excellence. The fact that the conclusion of the communication of the EC of February 15th 2012 makes a reference to ESA and "advocates for a similar strategic decision for HPC systems" seems to show EC's preference for strongly centralized models like the Central Operator Model. The EC directly funds 20% of the budget of ESA.

However, it is important to recall that this model is valid even without the EC contribution, as long as the countries strongly commit to the PRACE budget.

Contributions from the PRACE members to the PRACE AISBL can be fixed, with each country agreeing to pay a fixed share of the annual budget (much bigger than in the cycles model since it has to pay for the Tier-0 system), or could vary, with contributions depending on each country's GDP or with the usage in case of juste retour. Those options, stemming from existing examples, have been analyzed in D2.3.2.

As an example, the Table 4 shows how the initial five years investment of 400M€ for PRACE would have been distributed in terms of contribution based on GDP of the members:

Country	GDP Billion € (est. 2011)	%	PRACE investment for the initial 5 years period (M€)
Austria	322,66	2,29	9,17
Bulgaria	41,21	0,29	1,17
Cyprus	19,51	0,14	0,55
Czech Republic	167,21	1,19	4,75
Finland	205,39	1,46	5,84
France	2131,31	15,15	60,60
Germany	2754,46	19,58	78,32
Greece	236,81	1,68	6,73
Hungary	112,26	0,80	3,19
Ireland	168,73	1,20	4,80
Italy	1704,74	12,12	48,47
The Netherlands	651,46	4,63	18,52
Norway	363,80	2,59	10,34

Poland	403,64	2,87	11,48
Portugal	183,61	1,31	5,22
Serbia	33,32	0,24	0,95
Spain	1166,60	8,29	33,17
Sweden	433,85	3,08	12,34
Switzerland	505,43	3,59	14,37
Turkey	579,20	4,12	16,47
UK	1883,11	13,39	53,54
Sum	14068,31	100,00	400,00

Table 4: PRACE contribution by member's GDP

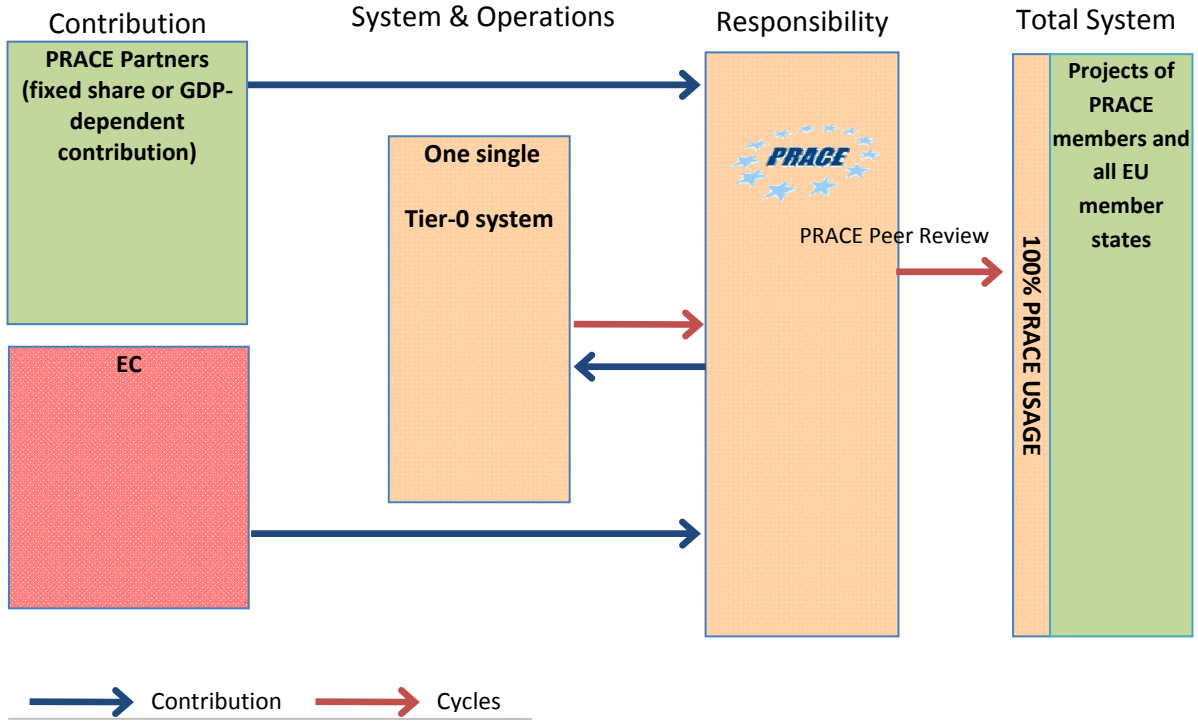

Figure 4: Central Operator Model

3.3.4. Operator model

	Single System	Multiple Systems
Cycle	-	Cycles
Machine	Central Operator	**Operator** / Co-owned Operator
Both	-	Hybrid

Table 5 : Position of the operator model

The Operator model, highlighted in Table 5 and schematically described in Fig.5, differs from the Central Operator model only in terms of number of Tier-0 systems managed by PRACE.

The Operator Model has been initially defined in D2.2.1. It represents a total transfer of responsibilities to the PRACE Organisation that funds and owns multiple systems located in different countries. The funding analysis of this model has been provided in the scenario referred as Central Organisation-Several Systems-Cash financing model in D2.3.2.

Unlike the Central Operator model, where all the resources are concentrated on a single (and probably very big) system, the Operator model offers a variety of Tier-0 systems. Although the systems deployed can be smaller in this model because of disaggregation of resources, the number of different architectures offered by the European infrastructure can be higher. Nevertheless this model shares all the elements defined for the Central Operator Model regarding: location, recruitment, negotiation of the counter value of hosting a system, and deployment plan.

The greater number of systems to be managed by PRACE increases the chances it will have to rely on existing infrastructures, especially regarding the operation of these systems. Potential in-kind contribution from hosting members (facilities, operating support, etc.), if mapped into an economic cost, can lead to smaller monetary contributions from these members.

As in the Central Operator model, funding models with or without direct contribution from the EC, and with fixed or variable contribution from the PRACE members are possible. Unlike in the Cycles model, the cost of sharing under this model is significantly high. If the infrastructure has three to five different Tier-0 systems operating with an estimated TCO of 20M€/year each during five years, that makes a total of 60 to 100M€/year to be funded. Assuming co-funding from the EC of 25 to 50%, the cost to share from partners under this model would be from 30 to 75M€/year. If under this model PRACE had from 10 to 20 members, the average cost to share per member would be between 1.5 to 7.5M€/year. It is just an average, to give an idea of the magnitudes, but it doesn't reflect the reality, nor take into account effect of a possible implementation of juste retour.

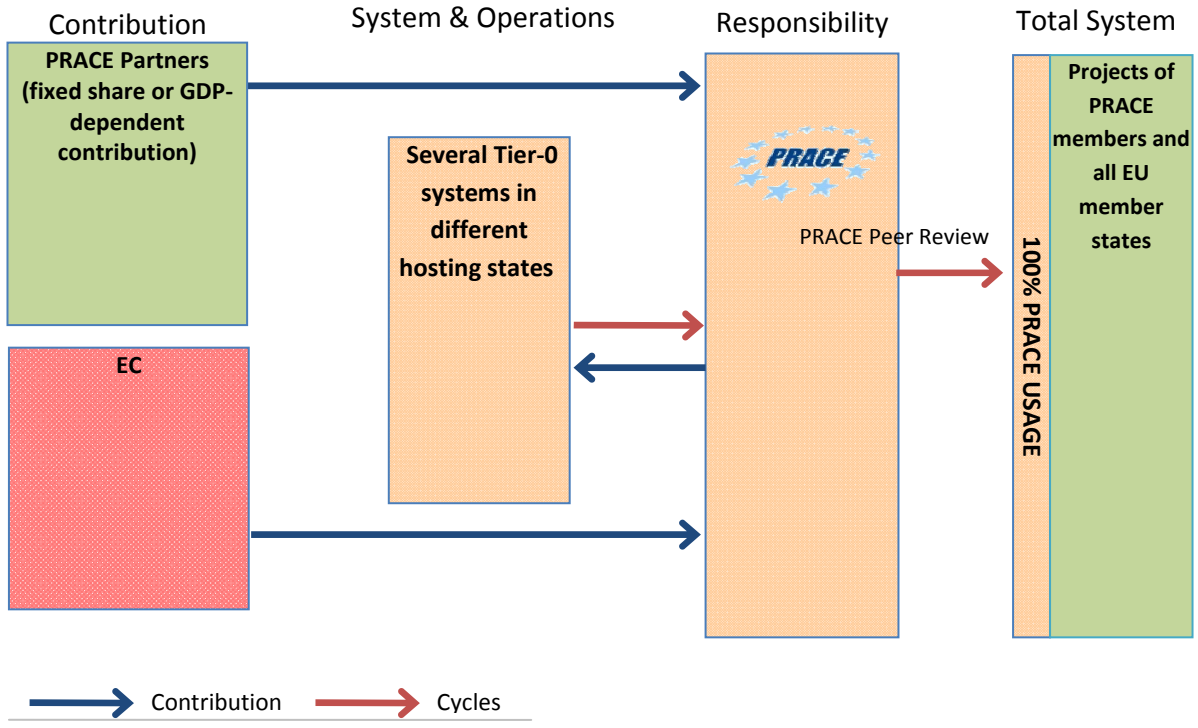

Figure 5: Operator Model

3.3.5. Co-owned operator model

	Single System	Multiple Systems
Cycle	-	Cycles
Machine	Central Operator	Operator / **Co-owned Operator**
Both	-	Hybrid

Table 6 : Position of the co-owned operator model

Under the Co-owned operator model, highlighted in Table 6 and schematically described in Fig. 6, each Tier-0 system is co-funded and therefore jointly owned by its hosting country and PRACE AISBL. The way they share the ownership can be realized in two ways: they can form a legal structure together that owns the system, or PRACE can let the hosting partner have the total ownership against formal commitment to associate PRACE on every important decision concerning the system. It is very unlikely that a country would give away its entire ownership of a system it funds (in a significant way) and hosts.

The distribution of cycles of the co-owned model is made such that each funding entity (PRACE and the hosting country) has a percentage of the cycles of the machine depending on the level of their contribution.

As well as for the Central Operator and Operator model, hosting a machine under a co-owned operator model could provide indirect benefits to the hosting member, although this one had to make also a significant investment in the systems. Hence the model has to also take into consideration the previously described elements regarding location selection, recruitment of staff, deployment plan and negotiation of the precise counter value of hosting a system.

A committee formed by members from both the hosting country and PRACE can be in charge of the procurement process. On the PRACE side, each co-investment in a Tier-0 supercomputer is part of a general deployment plan. This procurement committee can be the place where to negotiate a policy for distributing the costs (operating the system, electricity bills, facility, etc.).

Some of the variables to be negotiated between PRACE and the hosting country are listed in the following:

- Technical specifications of the procurement;
- Percentage of the cycles attributed to each funding entity;
- Distribution of the costs related to the machine;
- Responsibility of operating and monitoring the system.

Such as in the Operator model, this model drives PRACE to rely on existing national infrastructures and personnel while keeping some power to ensure that PRACE guidelines are taken into account.

The possible funding models associated with this scenario are the same as with the Central Operator model, except that the PRACE budget will be dedicated to co-fund multiple Tier-0 systems instead of entirely funding one (potentially) bigger system. In one way or another, every PRACE partner takes a share of the budget along with the potential direct contribution from the EC.

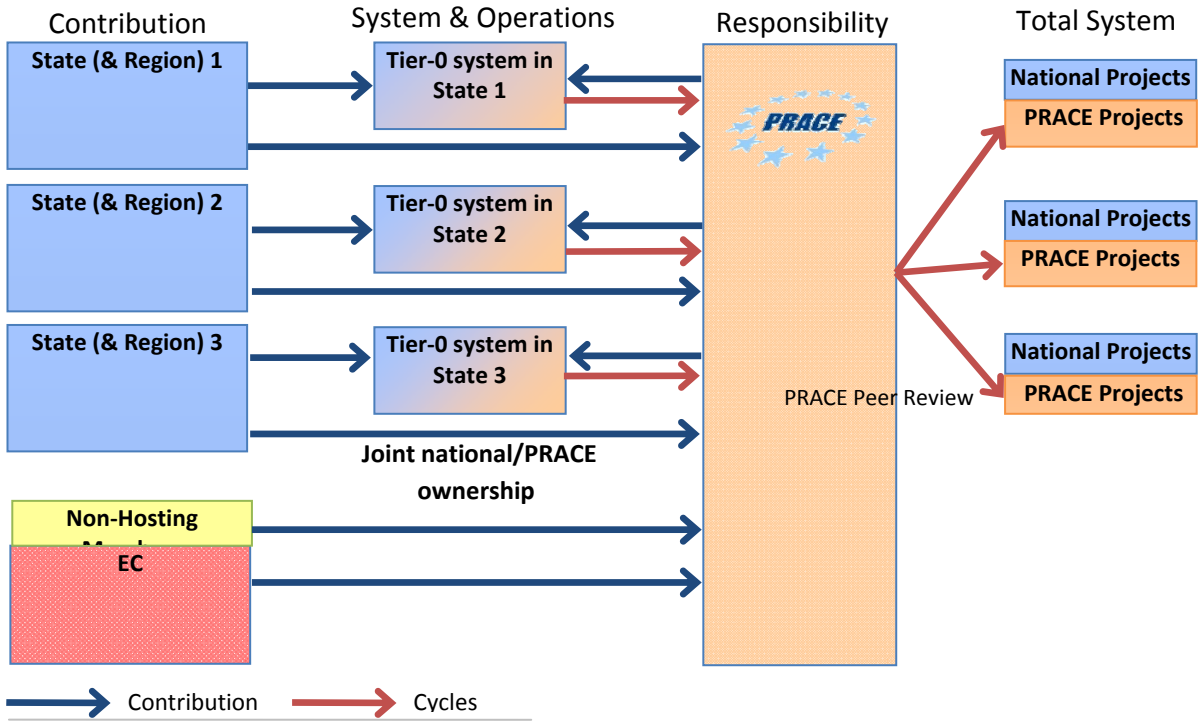

Figure 6: Co-owned Operator Model

3.3.6. Hybrid model

	Single System	Multiple Systems
Cycle	-	Cycles
Machine	Central Operator	Operator/Co-owned Operator
Both	-	**Hybrid**

Table 7 : Position of the hybrid model

The hybrid model, highlighted in Table 7 and schematically described in Fig. 7, is a combination between the Cycles model and one of the three operator models described above. More precisely, a set of Tier-0 machines are provided by Hosting Members under the Cycles model, which means that hosting countries owning those machines contribute cycles to PRACE and in parallel, other Tier-0 machine or machines are governed under one type of operator model, which means PRACE directly funds (or co-funds) the procurement of the system(s).

These two sets of machines share a common peer-review process and a related PRACE managing staff, but, since they work under different models, they are distinct regarding any other aspect. The detailed characteristics of these two sets, whichever operator model is chosen for the centrally-managed machines, have been described in the previous sections.

The deployment plan of the ensemble is complex, because the resources dedicated to PRACE are of two different natures: some belong to individual members, and some belong (at least partly) to PRACE. Ensuring consistency, in terms of providing a useful diversity of systems, requires frequent discussions between the AISBL and its HMs. If PRACE and national systems overlap in a significant way, it may lead to a lesser use of these systems and therefore to a detrimental investment for everyone.

The funding model is an aggregation of two different funding models. The Hosting Members contribute in-kind (cycles) and both Hosting and non-Hosting members, as well as the EC, contribute directly and in cash to PRACE in order to acquire centrally-managed top-class systems and to run the AISBL association. However the interaction from the different investments could force the creation of specific rules. The selection of the location of the machines under some type of Operator model would necessarily have to take into priority consideration the partners who contribute in kind under the cycles model. Also the distribution of costs for funding the Operator-Tier-0 systems would need to consider the significant expenditure on the Cycles-Tier-0 machine provided in parallel and might force the creation of special rules for these circumstances.

This model could be adopted if some national authorities have problems to contribute to a PRACE operated infrastructure, and the only possible way to contribute is through a national infrastructure made available to PRACE under the Cycles model. This way, the PRACE-cycles machines would be an alternative contribution to direct funding for the infrastructure. The specific value of the contribution would need to be negotiated.

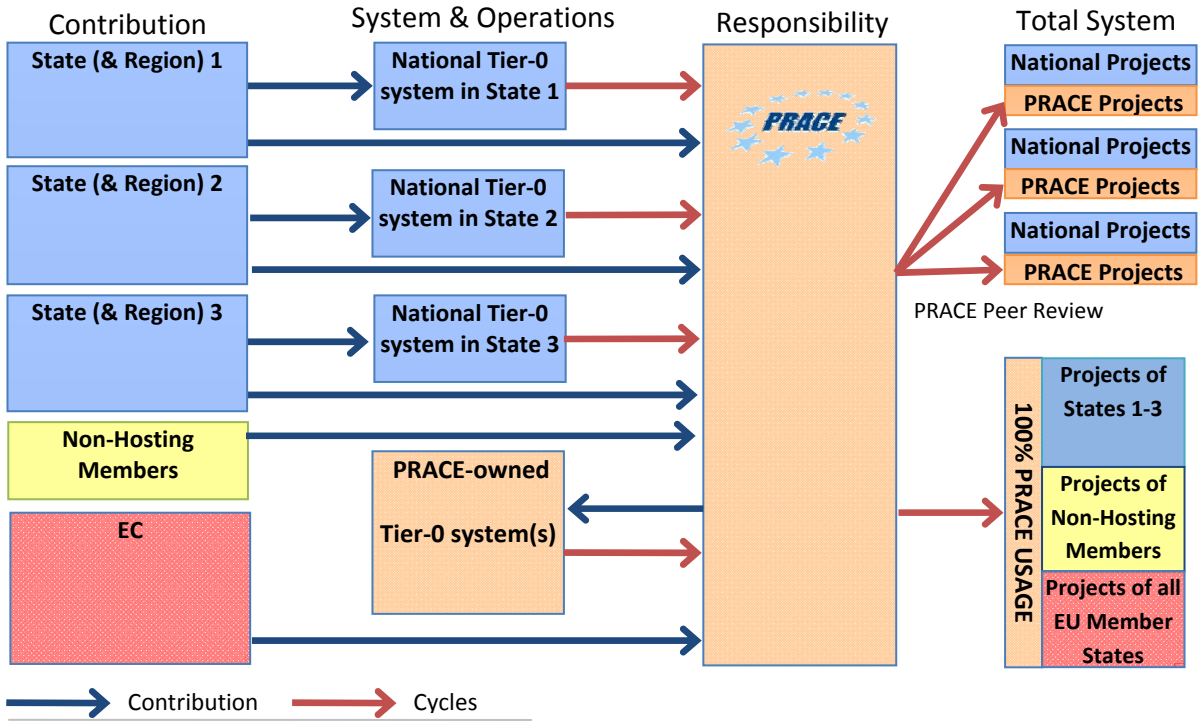

Figure 7: Hybrid Model

3.4. Strategy principles to evaluate the models

3.4.1. Explanation of the principles

This section gives a brief description of the principles that will be used in rating the following five scenarios that delineates possible operational models and indicate why the principles are important to PRACE. The principles have been defined by the deliverable D2.2.1.

Capability to reach PRACE AISBL technical and scientific objectives

This strategic principle stems from the mission and vision of PRACE AISBL as a world-class pan-European High Performance Computing service for all European researchers. The main goal of the PRACE AISBL is to make state-of-the-art HPC resources available to European researchers from academia and industry for promoting the best science in Europe and its economic impact.

The following sub-goals may be described more precisely:

1. Shared technical roadmap for supercomputer deployment in Europe, ensuring the complementarity of resources and their capacity to fulfil scientific and industrial requirements.
2. One of the goals is that the PRACE AISBL must provide leading world class resources. This definition must be rendered enforceable by maintaining an agreement between the PRACE AISBL Members regarding:
    a. the level of performance which pertains to this category;
    b. the time span of validity during which a particular supercomputer or supercomputer design is a valid candidate for acquisition and fielding;
    c. the required number of such supercomputers.
3. High quality single process for resource allocation based on scientific merit.
4. Accessing future innovative technologies and most relevant equipment necessitates keeping several channels to industry suppliers active.
5. Due to the high costs of the computing centres equipment, it is necessary to optimise with regards to several criteria:
    a. investment in facilities and training of technical personnel,
    b. design and iterative improvement of green low power consumption facilities,
    c. architecture choice, etc.
6. High quality service to the users including training, application support and developments, benchmarking of new programming techniques, etc.

Capability to set up Governance

Another important strategic principle is the capability to set up Governance, i.e. PRACE AISBL will need to coordinate the contributions of its members and will have to be able to decide on the general policy for governing the association.

The governance scheme must express the interest of a set of major stakeholders:

1. All participating members.
2. Hosting Members which may have made funding commitments as well as large investment in facilities, personnel, housing, etc. in order to accommodate PRACE AISBL Tier-0 systems.
3. Scientific communities which are represented through the PRACE AISBL Scientific Steering Committee.
4. Funding entities, notably national/regional and European.

Capability of making use of available expertise

Capability of making use of available expertise is very important for the success of the PRACE AISBL strategy:

1. PRACE AISBL should profit from being a Pan-European RI, with a large number of members, and as such should profit from key expertise available in the various member countries. This expertise is available through all PRACE AISBL member organisations and networks.
2. Also, the Hosting Members are contributing key expertise in deploying and operating world class systems.
3. PRACE AISBL also builds upon external projects or interest groups. PRACE also has connections with several FP7 funded projects such as EESI and follower EESI-2 which aims at creating an European exascale roadmap.
4. PRACE is building links with international HPC groups such as INCITE, XSEDE, etc.

A set of factors dealing with human resources may affect the ease of implementation of some operational models, especially regarding:

1. Local employment of specialists in a computer centre belonging to a different organisation of the same country;
2. Mobility resulting of employment of specialists in a computer centre belonging to an organisation of a different country;
3. Highly mobile scientists who need nevertheless to spend an extensive period of time at a site different from their home organisation. The mobility patterns may show quite frequent travel;
4. Careers of young researchers specializing in HPC.

While these issues are complex, the success of a site may ultimately depend on the quality of the personnel it can recruit. Success of cooperation may also depend in some cases on the possible mobility of key personnel between sites of different cooperating partners.

The scarcity of highly skilled HPC professionals may pose problems to the operational models with high staff requirements, so the exploitation of the available expertise should be also considered in terms of in kind contribution from the different members. In these cases, and in order to keep as much as possible the neutrality for PRACE, it should be considered any potential conflict of interest in the tasks they are assigned.

Capability to raise funding for long term sustainable operations

This is one of the most critical strategic principles. At the present time, funding comes mainly from the Hosting Members, and their contributions are vital to ensure the feasibility of PRACE AISBL.

Several criteria need to be considered:

1. It is critical that all PRACE AISBL members highly value the European access to a world-class HPC infrastructure through a single peer review process. Furthermore, a sustainable approach and long-term commitment is needed since HPC modelling and simulation need a long term vision and sustainable availability to researchers.
2. Concerning the Hosting Members, their acceptance of sharing the major part of the funding may result:
    a. from their commitment to developing the ERA,
    b. from their considerations of the worldwide scientific competition notably with regards to USA, China, etc.,
    c. from their expected return in terms of national scientific excellence and industrial competitiveness. Moreover, the Hosting Members permit the PRACE AISBL to

benefit from some level of mutualisation of the infrastructure (buildings, facilities, network, services) allocated to PRACE AISBL.

3. Non-Hosting Members benefit from access to the shared infrastructure, their expertise and know-how.
4. In the Central Operator model and the Operator model, there is no distinction between members (they all fund the AISBL according to their GDP, usage, etc.). In this case, it is important that all the members assess their commitment to sustainably take part in the budget of the AISBL and consider their expected return on investment.
5. All members of PRACE AISBL will expect return on investment in terms of Intellectual Property (development of new world class application codes) and the ability to recruit and train highly skilled scientific and technical personnel. Access to PRACE AISBL resources may give a competitive advantage to cooperative projects using simulation.

We need also to consider the key factors which motivate the EC to fund the project:

- Development of the ERA by providing world class HPC resources to the European scientific communities;
- Development of the European competitiveness and its societal impact;
- Support the EC Framework Programme objectives by providing access to key funded projects;
- Improve competitiveness of key pan-European RIs which can rely on the PRACE AISBL resources;
- European participation in world level scientific networks and cooperation;
- Support of world-class scientific research across Europe via a robust peer review process.

Various issues may also influence the motivation of funding members:

- Balance within members in terms of funding level, voting rights in the governance, members of scientific or technical bodies, etc.
- Capacity of funding members to commit: this may be dependent on national budgetary rules (for instance the budget is decided annually in some countries). In general, long-term funding commitments may be made in intergovernmental agreements.
- Substantial support from the EC may also facilitate the national decisions regarding funding of the PRACE AISBL by helping national policy makers of these funding countries to recognise the value of the PRACE AISBL for the European development and for minimising the economic differences between European countries.
- In designing such funding models, which could lead to different access routes to PRACE resources, additional measures must be designed to ensure fairness among the applicants. The selection of funding mechanisms for the EC (direct funding or project related) should be discussed with the EC, preferably under the auspices of the PRACE AISBL Council.

Involvement of several EC research programmes for PRACE AISBL funding is also important to create a common research policy for Europe covering all scientific fields that cannot achieve their present and future goals without the HPC resources made available by PRACE AISBL. This may imply a bundling of funding efforts from various directorates inside the EC for covering scientific fields as diverse as Economics, Fundamental Physics, Chemistry, Material Science, Medicine and Life Sciences and even Humanistic and Social Sciences.

Care must be taken when proposing evolution of the funding scheme:

- Unless other sources are available, it is important to maintain the commitment of the members to fund the PRACE AISBL, and therefore address their requirements.
- When looking at EC funding, it should be considered that it is most likely that the EC will only fund a fraction of the costs, and therefore PRACE AISBL members will be called upon to complete the round of funding. Here too, the requirements of all funding entities must be kept in mind.
- EU funding comes from European members. Both this and the member contributions are in danger of being affected by the current downturn in the economic climate.
- Some marginal funding can be contributed to the PRACE AISBL by its own activities (e.g. training). This funding may help cover the running costs of the PRACE AISBL organisation, but cannot be considered as a major source of income.

Capability to further support the objectives of building the European Research Area, or supporting ESFRI projects and other main European Policies or Priorities

Another important strategic principle is the support of the PRACE AISBL for the objectives of building the European Research Area and supporting other major European research projects and/or future policy decisions for European research. At present the PRACE AISBL receives advice from the Scientific Steering Committee, formed by prominent European scientists from various countries and covering all fields of computational science, regarding the access to the PRACE AISBL resources. Once again it is important that this advice is directed to a single organisation with a full pan-European character – the PRACE AISBL – instead of being spread through various committees and organisations that in some cases may issue contradictory advice on European research priorities.

Legal requirements

Legal requirements, mainly regarding the management of PRACE AISBL funding (either from member countries and/or the EC) need to consider a common strategy for taxation, especially in models that include elements of exchange of funding and services between the member countries. This strategic principle results from the distributed character of the PRACE AISBL, with supercomputers distributed through various countries and the possibility of various countries contributing with their expertise to the various services provided by PRACE AISBL. The full set of PRACE AISBL services (not only supercomputing access, but also training and user support, testing of new architectures in prototype systems, etc.) implies a distributed model for acquisitions and exchange of services between the PRACE AISBL and its members. This model does not exist yet and its implementation will request an agreement between the PRACE AISBL members. Here once again, the EC can have an important role to create the suitable regulations and possibly the legal framework to permit the necessary legal agreements between the member countries of PRACE AISBL.

3.4.2. Rating of the model towards the principles

The principles defined above serve as the basis for evaluating the models. The rating of a model toward a principle is the answer to the question: How hard or easy it is, under this model, to meet this principle?

With enough political will, enough funding, and enough effort, any model virtually allows to fully meet any of the previous principles. There is no incompatibility, but the difficulty to comply with a certain principle differs from one model to the one another.

Principle\Model	Cycles	Central Operator	Operator	Co-owned	Hybrid
Capability to reach PRACE AISBL technical and scientific objectives	**Medium**	**Medium**	**Easy**	**Easy**	**Easy**
	The Cycles model and the Central Operator model, in their operational schema, each present a risk that PRACE won't be able to deliver the state-of-the-art systems best suited for the scientific communities. In the Cycles model, there are only computers owned by national partners, with little incentive to grow beyond what is already nationally possible. Hence, there is a risk that there will be no system able to compete at the world level in terms of computational power and therefore no resources for scientific projects demanding enormous capability. On the other side of the spectrum, the Central Operator model only gives access to a single system, when scientific communities have different needs in terms of architectures. Hence, there is a risk that some scientific fields or some type of experiments won't be able to get the best from what is available through PRACE.				
Principle\Model	**Cycles**	**Central Operator**	**Operator**	**Co-owned**	**Hybrid**
Capability to set up governance	**Easy**	**Medium**	**Hard**	**Medium**	**Medium**
	In the Central Operator model, designing a governance effectively taking into account perspectives from all the stakeholders will be a challenge for such a centrally-managed organisation. A challenge which is even harder in the case of the Operator model, where decisions will have to be taken for multiple systems located in multiple countries. Shared ownership, a concept whose consequences are not very well known, necessitates a clear decision-taking process between the co-funding entities. Finally, the complexity of the Hybrid model will impact the ease of setting up a governance.				
Principle\Model	**Cycles**	**Central Operator**	**Operator**	**Co-owned**	**Hybrid**
Capability of making use of available expertise	**Easy**	**Hard**	**Medium**	**Easy**	**Easy**
	In the Cycles model (and therefore the Hybrid model) and the Co-owned model, the operation of the systems heavily (if not entirely) rely on existing staff and facilities. Computer centres act as an intermediate between raw access to the machines and PRACE. Naturally PRACE will benefit from this available expertise, as it currently does. Non-hosting countries are also invited to share their know-how in various ways. On the opposite, the systems are entirely funded by PRACE under the Operator and Central Operator models. Although the operation of the systems can rely on existing staff and facilities, making use of the available expertise, in those two scenarios, is achieved, for the most part, through hiring already well-trained people from the partners rather than through a truly collaborative process. This capitalization on existing expertise is even more limited in the Central Operator model, where having a single system means having less people to hire and				

	fewer countries actively involved in the PRACE daily activities.				
Principle\Model	**Cycles**	**Central Operator**	**Operator**	**Co-owned**	**Hybrid**
Capability to raise funding for long term sustainability	**Medium**	**Easy**	**Medium**	**Easy**	**Medium**
	As in D2.3.2, where it simply appeared as "Sustainability", this principle has to be understood not as the difficulty of the negotiations needed for transitioning from the current model to another one, but as the capacity, once the model is established, to have a vision on the long-term and to act and secure the funding accordingly. In this respect, it will be easier under the Central Operator model, where PRACE has full control over its assets and is focused on a single system, than under the Cycles model, where PRACE has little visibility (or at least binding commitments) of its members' plans for the near-future. In the Co-owned model, although it also depends on individual partners' willingness to repeatedly invest in new Tier-0 systems, the incentive of the co-funding from PRACE and the EC makes these investments predictable and therefore easier to fund. For instance, if co-funding from the EC is available and if PRACE publicly states that it is looking forward to substantially co-fund systems whose specifications are aligned with a certain roadmap, it is very likely that those systems will soon see the light. Once PRACE partners have agreed on the roadmap, it is fairly easy, under the Co-owned model, to secure long-term funding. In the Operator model, the number of systems makes the long-term funding sustainability a bit harder to achieve. The Hybrid model, as a combination of two different models, will have to address problems coming from both.				
Principle\Model	**Cycles**	**Central Operator**	**Operator**	**Co-owned**	**Hybrid**
Capability to further pursue the objectives of building the ERA or supporting ESFRI projects and other main European policies or priorities	**Easy**	**Easy**	**Easy**	**Easy**	**Easy**
	Whatever model is considered, it does not endanger PRACE's support to building the ERA and to other main European policies or priorities.				
Principle\Model	**Cycles**	**Central Operator**	**Operator**	**Co-owned**	**Hybrid**
Legal requirements	**Easy**	**Medium**	**Medium**	**Hard**	**Medium**
	For the Cycles model, being an extension of the current model, the legal requirements have already been analysed and addressed. For the other models, all comprising significant changes (tax status, legal form), it will be more challenging to meet these requirements, with an extra difficulty for the concept of co-ownership which needs in-depth legal analysis.				

Table 8: Rating of the models according to each strategic principle

3.5. Transition

Comparing the potential future models in terms of strategic principles is one dimension of the discussion about the evolution of the PRACE research infrastructure. It captures the long-term advantages and disadvantages of possible options, as well as the strategic vision underlying them.

Assessing what steps are required to change from the current model to the potential models analyzed in this deliverable is another dimension of the discussion, centred on the short-term prospects. The feasibility of the transition, and the difficulties that may arise in each case, have to be taken into consideration when discussing about the future model of PRACE.

One common difficulty in all the possible transitions lies in the dependency of the EC's contribution level. This will influence the decision of the PRACE model to adopt but at this point in time there is no clear statement from the Commission on this respect. The EC probably will not express its position until a model has been chosen by the partners. However, it is important to associate the EC in the discussion about the future models, so that PRACE can take into consideration the EC position where appropriate.

In the sections below, we describe the foreseen transition from our current model to each of the five scenarios previously considered.

3.5.1. Cycles to cycles (extension of the current model)

Although this option is an extension of the current model, it is nonetheless challenging in some aspects. The Agreement for the Initial period will come to an end in 2015. To continue under the same model after this period will therefore require another round of funding commitments. If the number of PRACE partners willing to become Hosting Members is too small, it could jeopardize the whole PRACE enterprise.

In a time when the level and mode of contribution from the EC is unknown and when the global economy still struggles to recover from a major downturn, achieving a national governmental support to further commit financially to the PRACE initiative at a Hosting Member level is not an easy task. In this respect, a deeper analysis of the *juste retour* principle is useful to give guarantees of ROI and reduced free riding.

The biggest and obvious advantage of this extension of the current model is that best practices and the current governance with its established bodies (BoD, SSC, AC) can be used to better effect. The continuity of the model will allow PRACE to further pursue the achievements of the initial phase, to keep using the fruitful collaboration in place and to assess the progress of PRACE on a longer and more significant period of time.

3.5.2. Transition to Central Operator model

To go from the current Cycles model to the Central Operator model is a change of paradigm. Instead of having several countries committing cycles that PRACE redistributes through peer-review, the countries contribute money so that PRACE can acquire one top-class Tier-0 system and manage it. Hence, the transition requires the setup of a much bigger organization than the one currently in place.

Firstly, since countries will need to give money for a system they do not own, securing the monetary commitments from all the PRACE partners is likely to require intense national lobbying. Prior to that, or maybe in parallel, a negotiation will have to take place to decide the

funding model: countries can agree to share the budget in a fixed way, but they can also decide to adapt the shares according to the GDP or even according to the usage of the machine (see section 3.3.3 for a more detailed description of the model). Those two aspects will lead to a late start of the transition. Here too, a *juste retour* policy, or at least some analysis of it, can help make the case for a renewed (and sometimes bigger) commitment from the partners.

Other issues will need to be discussed before the new model actually takes effect. The selection of the country, the machine and site to host the system will need to be subject to a rigorous selection and procurement process, whose criteria have to be clear and accepted by everyone. The technical specifications of the first system to be procured will need to be agreed upon and it may require a long negotiation to solve potential conflicts between countries preferring different systems. Finally, the legal form of the future PRACE site hosting the system, assuming it could be an ERIC for instance, can raise additional difficulties and lengthen the transition process.

In the meantime, an intense hiring process will need to be established. In a Central Operator Model, PRACE will need a much bigger legal, financial and technical staff with highly-experienced experts. This staff will be in charge of the procurement process for example. If PRACE decides to operate the system itself, a whole crew is required to do so. If PRACE decides to subcontract the operation, it will still need supervision and some work to define the subcontracting policy. A governance structure for the site and other necessary processes will need to be implemented.

Such an ambitious transformation project for the PRACE infrastructure requires a heavy planning to set up the transition process. Using the existing expertise, facilities and crew, will ease this transition but, given the time it will take anyway, it is realistic to consider putting in place a transitory model which will run until all the issues are cleared. For instance, the current Cycles model could be extended beyond 2015 for the amount of time necessary to agree on the major decisions. In this case, one also has to think about the compensation scheme for the countries that contribute during the transition.

3.5.3. Transition to Operator model

In addition to all the aspects of the transition to a Central Operator model, adopting an Operator model (same model but with several systems in several countries) requires the definition of a deployment policy. This policy will determine the periodicity which PRACE will acquire its systems with, criteria about the locations of the systems, and some rules about the desired diversity amongst the machines that PRACE will own and operate. This policy, along with the technical specification of the first machine(s) to be procured by PRACE, will require a lengthy negotiation between the partners.

The national lobbying necessary to raise the funding will be harder than in the Central Operator case, because of a bigger budget (several systems) and because of most -if all- of these systems won't be located "at home". The hiring process, maybe even more extended than in the Central Operator model, that is needed for PRACE to be fully operational in its new role, will also take a long time.

Hence, here too, it might be good to consider a transition period beyond 2015 that will keep the organization in place while preparing for the Operator model. This transition is most easily realized with the continuation of the Cycles model, at the condition that a compensation scheme ensures fairness for partners contributing during the transition.

With several hosting countries, legal issues can also be of a different nature under each hosting country's national law, and therefore might render the transition more complex.

3.5.4. Transition to Co-owned Operator model

In terms of transition, the Co-owned Operator model shares most of the advantages of the Cycles model, meaning it requires a lighter transition than any other Operator model. Indeed, each system is co-owned by the hosting country, which means that there will be national staff in place on which PRACE can rely on. The decision on the location of the systems will also be straightforward: countries that can secure funding are eligible to act as hosting members. It is then PRACE's choice to participate or not to the joint funding of a system.

However, unlike under the Cycles model, PRACE might need to hire staff able to be in charge of procurement together with the national counterparts. Even in the case of a national staff doing most of the procurement work, PRACE needs to make sure its decisions are implemented correctly. A general policy to take such decisions regarding the joint procurement is required, as well as a general policy for deciding which centres or countries are qualified for the co-investments.

Also, because of the complexity of the notion of shared ownership and the consequences it could have, a legal analysis of this concept prior to any decision is needed.

As for any other operator model, getting the national partners to commit to fund a significant increase in the AISBL's budget will require intense lobbying. Moreover, one has to make sure that there will be enough countries willing to host and co-fund Tier-0 systems with PRACE, otherwise this model might not fulfil PRACE's mission. One other risk is if each country wishing to co-fund a system is willing to do so only on conditions that don't exactly meet PRACE's requirements, for instance if no member wants to co-fund a system of a specific architecture desirable for PRACE. To avoid these risks, it is important that PRACE members collectively agree upon guidelines to implement the transition and prevent these situations to happen.

3.5.5. Transition to the Hybrid model

The Hybrid model combines a Cycles model with one of the Operator model, de facto creating two sets of Tier-0 computers running under two different models. Therefore the transition to the Hybrid model would be likely happen in two phases. First, a continuation of the current cycles model for systems capable of being entirely funded nationally, and second, on top of it, a slow building of an operator model for bigger systems that need joint effort from countries and the EC.

The combination of two models in this Hybrid model makes some aspects of the transition more difficult. For instance, lobbying nationally for both cycles and money will be harder, or at least will require some time to better explain the model and its perspective. The discussion on a *juste retour* policy will also be more complicated, since it will be trickier to evaluate precisely what return of investment can be expected from this type of hybrid model. A specific reward policy can be implemented under which the locations of the PRACE operated systems are attributed depending on the amount of cycles contributed by the nationally operated ones. Then, the counter value of hosting a system can be assessed and included in a ROI analysis.
Setting up an Operator model for the upper layer will encounter the same difficulties as described previously, e.g. going through an intense hiring process, defining policies for

procurement and governance, agreeing on a specific funding model and possibly on a different legal form, deciding a deployment plan and criteria for locating the systems.
It is interesting to note that this model can be used as a bridge to an operator model. During the first phase of the transition, the cycles model is extended, then, once it is mature enough, a central operator model (or operator model in case of several systems) runs in parallel. Then, gradually, if desired and maybe synchronized with the decommissioning of national systems, resources available under a cycles model decline only to reappear on a new PRACE-operated supercomputer. In the end, it can become a pure operator (or central operator) model.

4. Conclusions

This deliverable has shown the outcome of the research on the options for PRACE operational and procurement models. The analysis performed has taken as input the PRACE context in its status-quo until April 2012. While the analysis identifies different possibilities, it does not pretend to give advice to transiting into any one in particular. The analysis focuses on identifying the challenging areas in the different options. The different options and the analysis made should feed the discussion of the management bodies of PRACE RI for evolving from the current model that expires on 2015.

Two categories of analytical factors have been identified in the analysis; on the one hand, a set of general factors influencing the decision labelled as "key drivers" are described. On the other hand the "strategic principles" - previously identified in D2.2.1 - have been used to compare the different models. The key drivers identified are: the heedfulness for the mission of PRACE and the user communities requirements, the goals of members and the possibilities of leveraging their existing assets for PRACE, the services to be provided and necessary renewability of systems, the legal aspects to be dealt with and the EC and EU plans and commitments towards PRACE. On this last factor, the support of the European bodies to the HPC area - recently requested in a Communication to the Parliament - is closely related with all the other factors since this support is key for the sustainability of different models. However at this point in time there are still uncertainties on the specific support vehicles that will be provided to PRACE and depending on these, some of the models analysed may not be possible.

The procurement models have been analysed separately from the operational models since in principle any procurement mechanism could be applied in any operational model and moreover multiple types of procurements can be used in parallel in any model (e.g. Competitive dialog for "standard" systems and PCP for further down the road prototypes). At this point in time the decision on the particular procurement model to use is less binding than the operation model. The models considered are the competitive dialog, pre commercial procurement and public-private partnership. Nevertheless some elements of the procurement need to be considered in the operational model discussion. These elements are: the funding to pay for the procurement, the affiliation of the personnel who performs the procurement, the procedure to agree on specific options to be procured for PRACE and the legal issues of having trans-national procurement (which would be dealt in the pilot PCP exercise during PRACE-3IP should this project be approved). The analysis revealed a purchasing option that can be of particular interest for consideration to PRACE, namely the option of renting or leasing systems. Further analysis is advised in this area since the lack of ownership of the systems could be key for avoiding different legal issues related to shared ownership, possession of assets in the association, or tax status.

The operational models identified differ in: the number of Tier-0 systems, the assets that PRACE RI owns, and the shared ownership of these. Out of the multiple combinations of these parameters, the analysis has just focused on the only plausible models. These have been described and compared according the strategic principles.

The Cycles model, by which PRACE is currently operating, has proved effectiveness to engage 24 countries in the infrastructure. The model has fulfilled its purpose of coordinating European countries to have a joint agenda for deployment of Tier-0 systems and strengthening commitments for the sake of the HPC development in Europe. However the analysis made in this task and in task 2.3 [4] under the financial perspective showed that this model needs to design a mechanism to ensure *juste retour* to make the model financially sustainable and

operational. An explicit *juste retour* policy would ease the task of furthering the necessary financial commitments. This model can also accommodate different co-funding schemas that would facilitate its sustainability. In terms of transition, the Cycles model, is the less demanding option compared to the others.

The Hybrid model is a combination between the Cycles model and one Operator model (of any sub-type) coexisting in parallel. The interaction from the different investments could force the creation of specific rules for, for example, compensating in kind investments under Cycles model. This model could be adopted when some national authorities would have problems to contribute to a PRACE operated infrastructure, and the only possible way to contribute is through a national infrastructure made available to PRACE under the Cycles model, although this is not the only possible scenario for this model to be considered. This model could be also considered when some members want to keep the ownership of their national systems and still provide service to Europe, and at the same time contribute in a joint system. Another possible scenario for this model to happen would be as a bridge to an operator model by which Hosting Members under cycles model still need to fulfil their commitments while the consortium has already started to implement a PRACE owned machine.

Any operational model could accommodate EC direct funding on the infrastructure, however for the Co-Owned model, there is a more straightforward mapping if the cost of the system to be covered by PRACE is paid directly with European funds. The feasibility of this model is likely to be directly linked to having such a funding option available. In any case, the model has also internal challenges for its deployment since despite the funding support shared ownership could be a problem to deal with in different aspects: for deciding the systems to be procured, distributing the cycles, distributing the costs, operating the systems and securing significant funding under a partial ownership of a system

Two types of operator models have been analysed: the Central Operator (with just one system) and the Operator (with different systems). The analysis identified the elements that the organisation should need to agree on in order to adopt the model, revealing the difficulty in the process from different perspectives (political, financial legal and operational). The processes for transiting to any of these options are very demanding. Putting forward the message of the importance of the investment of this model despite the procured systems will not belong to the contributors, represents nowadays a difficult challenge that might delay a straight transition from the current cycles model to the operator model. Other elements such as the country selection, and the recruitment of personnel would need to be dealt with, and finally it is necessary to be aware that the mission of PRACE is compromised in the Central Operator model by having a single type of Tier-0 architecture available in Europe that might not be suitable for every user community.

A comparison has been made for each of the models analysed against a set of strategic principles. The Table 9 summarises the comparison where each cell indicates how difficult is to meet a specific principle relatively to the other models:

Principle	Cycles	Central Operator	Operator	Co-owned	Hybrid
Capability to reach PRACE AISBL technical and scientific objectives	Medium	Medium	Easy	Easy	Easy
Capability to set up governance	Easy	Medium	Hard	Medium	Medium
Capability of making use of available expertise	Easy	Hard	Medium	Easy	Easy
Capability to raise funding for long term sustainability	Medium	Easy	Medium	Easy	Medium
Capability to further pursue the objectives of building the ERA or supporting ESFRI projects and other main European policies or priorities	Easy	Easy	Easy	Easy	Easy
Legal requirements	Easy	Medium	Medium	Hard	Medium

Table 9 : Summary table of the evaluation of the models against the principles

A simple evaluation of the previous table assuming equal importance to each strategic principle would reveal slightly more difficulties in meeting the strategic principles for the Operator and Central Operator models, and slightly less difficulties in meeting the principles for the Cycles model. However, the relative importance of each principle is arguably different to each other so this analysis should not be considered conclusive and just identifies the most complex areas to further investigate for each model in case PRACE has interest in transiting to a particular one.