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Continuity Plan for the PRACE Advanced Training Centres

Final

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D4.1**Continuity Plan for the PRACE Advanced Training Centres**

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[6] **V.Betro,** *XSEDE Training, Education and Outreach Activities,* presented at CUG2013, Napa, US.

[7] For a full presentation of the statistics see the *PRACE-3IP WP4 Quarterly Report for March – May 2013.*

[8] **M. Ostasz and S. Requena.** *D5.2 PRACE Integrated HPC Access Programme for SMEs: Partnership for Advanced Computing in Europe (PRACE-3IP)*, 2013.

List of Acronyms and Abbreviations

BSC	Barcelona Supercomputing Center (Spain)
CINECA	Consorzio Interuniversitario, the largest Italian computing centre (Italy)
CSC	Finnish IT Centre for Science (Finland)
DEISA	Distributed European Infrastructure for Supercomputing Applications. EU project by leading national HPC centres.
EESI	European Exascale Software Initiative
EPCC	Edinburgh Parallel Computing Centre (represented in PRACE by EPSRC, United Kingdom)
ETP4HPC	European Technology Platform for High Performance Computing
EUDAT	European Data Infrastructure
FZJ	Forschungszentrum Jülich (Germany)
GENCI	Grand Equipement National de Calcul Intensif (France)
HiPEAC	European Network of Excellence on High Performance and Embedded Architecture and Compilation
HLRS	High Performance Computing Center Stuttgart (Germany)
HPC	High Performance Computing; Computing at a high performance level at any given time; often used synonym with Supercomputing
ITN	Initial Training Network
ISV	Independent Software Vendor

MdS	Maison de la Simulation (France)
OMB	(PATC) Operational Management Board
PATC	PRACE Advanced Training Center
PGAS	Partitioned Global Address Space
PRACE	Partnership for Advanced Computing in Europe; Project Acronym
SHAPE	PRACE Integrated HPC Access Programme for SMEs
SPRINT	Simple Parallel R INterface
SSI	Software Sustainability Institute
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
XSEDE	Extreme Science and Engineering Discovery Environment

Executive Summary

The aim of this deliverable, *D4.1: Continuity Plan for the PRACE Advanced Training Centres*, is to present various options for continuing the operation of the PATCs beyond the end of the PRACE-3IP project. Continuity is considered in terms of sustaining the demand for and supply of HPC training material, as well as in financial terms. We review the operation of the current six PATCs from March 2012 to March 2013 and conclude that, overall, they have been very successful: a total of 4462 participant-days have been delivered with an average overall feedback rating of 8.5/10. The management and operational structure of the PATCs is also working well, with advice being taken from an external panel of experts. An analysis of the full costs of delivering training also shows that this is being delivered in a very cost-effective way for PRACE, with substantial in-kind contributions supplied by the PATC partners. However, the statistics also show that a great majority of course attendees are based in institutions in the same country as the PATC itself. We consider the future of HPC training in the EU and conclude that demand is likely to continue to increase and that there many opportunities for the PATCs to meet this demand. It would also be desirable for the PATCs to increase their collaboration and coordination with other training projects and organisations. Addressing these needs would be helped by greater flexibility in planning and financing the PATC activities, for example to enable PATCs to do more training in non-PATC countries or to better respond to changing requirements. Other training-related activities within PRACE such as the successful seasonal and international schools, and the Summer of HPC, should also be continued if possible as they are complementary to the PATC activities and address the issues of trainee mobility. We identify a range of eight options ranging from delivering a complete service with the best impact, down to a baseline level which maintains basic operations but is not sustainable in the long term. We estimate the total annual funding (both staff and non-staff) required for each option, which ranges from 89 PMs and 484 Keuro, to 57 PMs and 171 Keuro. Charging attendees at the maximum affordable level could potentially reduce the non-staff costs, for example by 135 Keuro in the baseline case, but this would undoubtedly reduce the number of attendees. We hope that these scenarios will be valuable input to the PRACE association regarding the on-going strategy discussion for PRACE 2.0.

1 Introduction

Training has a crucial role in ensuring that the end-users of the PRACE (Partnership for Advanced Computing in Europe) are able to use computing resources provided by the research infrastructure effectively and are able to take advantage of new technologies and methods in high-performance computing (HPC). The PRACE implementation projects have been actively developing and implementing a wide array of training activities to this end. Besides the very successful Seasonal Schools and other training activities, a more permanent training network was also initiated [1] in the form of the PRACE Advanced Training Centres (PATCs) established in early 2012 [2]. Starting operations in March 2012, the network of six PATCs – at BSC (Spain), CINECA (Italy), CSC (Finland), EPCC (UK), GCS (Germany) and MdS (France) – has proven to be very successful with more than 1300 trained students, and receiving very positive feedback from students and an external review panel alike.

Training continues to be a key area of HPC, ever more so as we face the challenges of Exascale and a rapidly changing hardware and software environment on high-end systems. To provide long term support for world-class computational science in Europe, it is important for PRACE to continue its successful training activities and the operational PATC network offers a proven successful channel to realise this goal. At the moment, funding for the PATCs is secured almost until the end of PRACE-3IP, i.e. April/May 2014, after which a new, sustainable model is needed for the PATCs to offer a permanent PRACE training service as part of the core provision.

In this document we present a Continuity Plan to sustain the PATC programme beyond the end of the PRACE-3IP implementation phase. This is an important opportunity to address any aspects of the existing operational model that could be improved, and to consider extending the PATC remit to include other training-related activities of importance to PRACE.

When discussing sustainability, it is important to note that this has four distinct aspects:

- a. Sustainability in terms of the ongoing **demand** for HPC training which may involve expanding the current range of PATC activities.
- b. Sustainability in terms of ensuring the **supply** of relevant HPC training, both to support an expanding user base and to respond to emerging needs.
- c. Sustainability in **financial** terms, which requires an understanding of what the current PATC funding model does and does not cover and what could be covered in the future, in addition to potential funding sources.
- d. Sustainability in terms of establishing PRACE's continuing role in the HPC training ecosystem and its relationship to national, community and other training provision.

It is important to recognise at the outset that HPC training across Europe as a whole is already sustainable in some form: this is clear because the establishment of the PATCs in such a short timescale was only possible because they built on substantial existing training activities. Proven expertise in HPC course development and delivery was a pre-requisite for a centre to become a PATC. The current PRACE funding only covers part of the additional costs associated with delivering courses, but not other costs such as course development. These other costs are effectively in-kind contributions from each centre, which must be funded by other means (e.g. national training funding associated with running a national supercomputer service). This is equivalent to the already accepted view on the hardware side that PRACE funds the peak of the HPC supercomputer pyramid: for this model to succeed as it does, it clearly requires there to be substantial ongoing and sustainable hardware investments on smaller systems (Tier- 1, 2, 3, ...) across Europe, already funded by other means.

Note that, right from their inception, continued PRACE funding was envisaged: "After PRACE-2IP, financial support (not necessarily 100%) may come from subsequent

implementation phase projects or the persistent PRACE association. Some level of funding from PRACE is to be expected in the foreseeable future.” [1]

The report contains the following sections:

1. Introduction
2. Background
3. Lessons Learned
4. Future Opportunities
5. Funding
6. Scenarios
7. Options
8. Conclusion

This is an ideal time to be considering the continuity of the PATCs as they are now operating in a stable and successful manner with a well-established management structure. We have almost completed the first full cycle of training (curriculum, delivery then revised curriculum) and the Operational Management Board (OMB) coordinates this process. The Curricula Advisors review panel has also been set up by the PRACE BoD, giving the PATCs independent external advice from a panel of experts.

2 Background

The PATCs have been running since March 2012, with the first joint curriculum starting in September 2012. In this section we briefly review the current operation of the PATC programme and how it relates to other PRACE (and non-PRACE) training activities. We outline some non-PRACE activities as potential examples of other training models that could be followed, or examples of other activities that PRACE could collaborate with in the future.

It is important to recognise that there is not enough HPC training provision at the moment, that demand is growing and that lack of access to training is a barrier to wider uptake of HPC both by academic and industrial users. As there are other non-PRACE computational science training activities emerging in Europe, PRACE needs to be careful to choose the correct areas to focus on.

2.1 Current PATC programme

The process for arriving at the joint PATC curriculum is described in [2]. Here we give a short overview of the first year of operation (statistics are for 13 months until March 2013 inclusive) of the six PATCs, highlighting points of most relevance to future sustainability.

Up to March 2013 the PATCs have delivered:

- 60 courses;
- 176 course-days;
- 1394 participants;
- a total of 4462 participant-days.

On average, the courses had:

- 15% female and 85% male attendees;
- 91% from academia and 9% from non-academia;
- 81% of the participants coming from the country where the course was delivered;
- 6% coming from the other PATC countries;
- 13% coming from other countries.

As far as the quality of the training is concerned:

- 66% of participants filled in the online feedback form;
- average score for the courses was 8.5/10.

All PATC course administration (e.g. timetables, course material, registration and feedback forms) takes place through a single portal <http://www.training.prace-ri.eu/>. The INDICO system, developed at CERN, has proved very successful in managing the registration process.

In April 2013 the proposed curriculum for academic year 2013-14 was reviewed by an external panel of experts, commissioned by the PRACE BoD, which also considered the way the PATCs were operating. Feedback from the panel was very positive [3], and they made a number of important recommendations. The recommendations had two main themes:

- a. The PATCs should be flexible in satisfying the training requirements of the entire EU HPC community, adapting the courses offered to fit the wide range of needs and collaborating with other projects and HPC communities.
- b. The PATCs should aim to attract an even wider range of attendees by extending their geographical coverage and collocating training with other events.

The review was very timely and the recommendations of the expert panel have been considered very seriously in this report.

2.2 PRACE HPC training activities

At the end of 2011, a wide-ranging training survey was undertaken of HPC trainers and trainees across Europe [4]. The results of this survey were used to inform the PATC curriculum, the most important points being:

- a strong preference for face-to-face delivery of hands-on training;
- the most preferred length of course was between 2 and 4 days;
- although 71% of respondents had received university training in general programming, only 20% had received such training in parallel programming.

Other PRACE training activities which pre-date the establishment of the PATCs are the Seasonal Schools and the annual joint PRACE/XSEDE European-US Summer School; PRACE also organised a very successful Summer of HPC programme which started after the PATCs. Of these, the Seasonal Schools potentially have the most overlap with the PATC curriculum so some thought went into ensuring that they are distinct. PRACE-3IP WP4 [5] recently conducted a review of the Seasonal Schools and concluded that:

- the seasonal schools concept is complementary to the PATCs;
- they should be continued beyond the end of PRACE-3IP.

The PATC curricula review panel also noted that the Seasonal Schools played an important role in widening the geographical spread of PRACE training [3].

The way that the Seasonal Schools and the other PRACE training can be integrated into a sustainable PATC programme is addressed in Section 6.

2.3 Non-PRACE HPC training activities

The PATCs exist within a much wider ecosystem of training across Europe. Each national facility will typically have an associated training activity covering the use of that particular system, but also addressing wider issues such as basic parallel programming techniques or computational science in general. Most centres are funded to deliver more HPC courses than required by the PATCs, so must make a distinction between PATC and non-PATC courses.

Rather than being based at a particular HPC centre, HPC user communities often organise their own training activities, e.g. based around popular parallel packages. There are many EU-funding schemes specifically aimed at training, e.g. the Initial Training Networks (ITNs) are also aimed at addressing the needs of specific scientific communities, some which will have be projects with an HPC component.

The HPC Europa programme (<http://www.hpc-europa.eu/>) was an extremely successful EU project which promoted transnational access for researchers in HPC. A researcher would typically be funded to spend two or three months at a remote research group associated with an HPC centre, collaborating with the group on the science and receiving computational support from the centre. Although training was not an explicit part of HPC Europa, it was implicitly assumed that the researcher would have access to any training provided by the centre. However, it is clear that there was a very high demand for training: for example, when it was explicitly provided in the TRACS project (an EPCC project that was a precursor to HPC Europa) it proved incredibly popular and was massively oversubscribed.

Internationally, perhaps of most relevance to the PATCs is the training programme of the US XSEDE project. We have contacted several personnel involved in XSEDE training (Sam Moore, Jim Ferguson and Vince Betro [6]) to compare their provision with that of the PATCs. There are similarities in that XSEDE partners receive some funding to cover course running costs, but not course development or maintenance. More use is made of live webcasts (although this is complicated by the four US time zones) than the PATCs, although the fundamental model of hands-on training is very much the same. However, the PATC programme appears to be more coordinated and centralised than XSEDE. Although there is a central XSEDE dissemination and registration portal, there is for example no XSEDE equivalent of the PATC curriculum which aims to maximise coverage of topics across all the centres and minimise duplication of content.

3 Lessons Learned

This section covers the issues that need to be addressed if the PATCs are to reach their ambitious long-term aim of being “European hubs of advanced, world-class training for researchers working in the computational sciences” [1] in addition to being centres that deliver their own programmes of excellent training.

3.1 Access to training centres

The PATCs have been very successful so far: a large number of attendees have been trained in a wide range of HPC topics, and have given very positive feedback. However, one statistic that stands out is the small number of people who have travelled to a PATC event outside their own country. To take into account variations across countries, we have analysed attendance data in terms of participants per year for every 1000 students studying relevant scientific disciplines (i.e. representative of the size of our target audience) in each country [7]. This metric is on average 0.38 for students from the PATC countries, whereas for the other EU and PRACE countries it is only 0.04.

The fact that attendees find it difficult to travel is not unique to the PATCs. HLRS in Germany has data from six years of running a 5-day parallel programming course (delivered in English, as are all the PATC courses): about 45% of the participants came from the local city; 17% travelled from other cities within the same state; 31% from other states within Germany; only 8% from outside Germany. CINECA in Italy also has several programmes with international students attending non-PATC courses held in English, e.g. a 10-day parallel computing school. Over the last two years, about 30% of the school participants came from the local city, 17 % from cities from the same region, 38% from other regions in Italy and 15% from the rest of Europe.

The access to PATC courses for students from the same country as the centre varied between 0.20 and 1.06 students per year for every 1000 students studying the relevant discipline, but this variation is primarily due to the large differences in population (all PATCs run roughly the same number of courses). Note that the actual HPC provision may be substantially larger due to non-PATC courses. For the current PATC countries, there are typically more training courses delivered outside the PATC than within it. These courses are usually complementary and may differ somewhat in focus, e.g. they might not be as advanced as the PATC courses or may be delivered in the local language.

All PATC courses so far have been run in a PATC country, the vast majority at the PATC host site. A researcher living in a member state that hosts a PATC is less likely to have to travel abroad as each centre runs a relatively complete programme of core courses. Even taking into account that the six PATC countries cover a substantial fraction of the HPC users in Europe, it still appears that there is an issue with the current model in terms of accessibility of training to those in non-PATC countries. Although the training portal in principle enables distance learning, this does not solve the problem completely as the PRACE training survey [4] showed a very strong preference for face-to-face training courses.

Possible ways of addressing this depend on the level of the course. For introductory courses there is potentially a large audience in those countries without an established history of HPC research, i.e. non-PATC countries by definition. In countries already strong in HPC there are likely to be other training programmes that can provide some similar courses. However, where HPC is an emerging technology, the PATCs may be the only route to access this training. Fortunately, the introductory courses are likely to attract many attendees so it would be cost effective to run these in non-PATC countries with only a few trainers having to travel.

Ideally the host site could also use the PATC course as a vehicle to train their own staff, who could go on to deliver that course in the future without the need for direct PATC involvement (other than perhaps some ongoing support of the remote trainers). This model of having an explicit remit to train the trainers is already employed by the UK's Software Sustainability Institute (SSI) for their Software Carpentry training, and was adopted because the demand for this training greatly exceeds the SSI's capacity to deliver it by itself. One current issue with our funding model is that PATC money cannot be used to support the travel of PRACE staff; this must come from the already overcommitted WP travel budget which is a strong disincentive to PATC trainer mobility.

For the more advanced courses, there is not likely to be a sufficient audience to justify sending trainers to country with a less experienced or smaller user base. It is also unlikely that there will be enough qualified trainers in that country to enable them to run the course independently in the future, and there may even be issues with access to appropriate HPC hardware resources. In these cases it would be more cost-effective to make it easier for attendees to travel to the PATCs, for example by offering travel bursaries (see Section 6.2.3). Although this is possible in principle within current arrangements, it has not been widely adopted as a policy.

These issues of access to training are currently being addressed to some extent by other activities. For example, the locations of the PRACE seasonal and international schools have been primarily chosen in non-PATC countries in order to complement the PATC activities. For these events, the normalised attendance figures are 0.03 (students from PATC countries) and 0.07 (non-PATC), i.e. an attendance ratio of two in favour of non-PATC countries for the seasonal schools as opposed to a factor of ten against for the PATC courses. Other EU programmes such as HPC-Europa (<http://www.hpc-europa.eu/>) have addressed the issue of researcher mobility. However, there is currently no plan for sustaining the seasonal schools beyond PRACE-3IP unless they are subsumed into the PATC activities; the HPC-Europa programme finished at the end of 2012 and there are as yet no concrete plans for a replacement.

Access to training is therefore a major current issue in terms of promoting HPC to the whole of Europe, and the PATCs are in an ideal position to address it should they be provided with the mandate and funding to organise Seasonal Schools and "off-site" PATC courses at non-PATC countries.

3.2 Curricular flexibility

The PATCs are currently required to draw up a detailed curriculum of courses for a whole year, and because this has to be done at least six months in advance of the start of the year it means that PATC activities are fully planned up to 18 months in advance. The major advantage of this is that it ensures a coherent programme across all six centres, which is advertised and administered centrally. However, it does have the disadvantage that the PATCs are less able to be flexible. For example, a PATC might find out at a few months' notice that a world-leading expert will be visiting the centre and would be happy to deliver a training course. With the current arrangements this is difficult to accommodate into the PATC programme as all the PATC resources will have been committed to planned events. Similarly, a PATC might be approached to deliver training at a workshop organised by a particular HPC user community; again, this does not sit comfortably with the planned curriculum unless it was arranged almost a year in advance which is unlikely to be the case in practice.

A solution might be to plan most of the curriculum as done currently, but to retain some fraction unplanned if desired. There is only a small risk of these unplanned events not being

filled as their status can be monitored closely at the regular PATC meetings, and this can be further reduced if all PATCs have to propose potential backup courses from the outset. There are some possible complications in marrying a fixed up-front funding model with a more dynamic delivery model – these are addressed in Section 6.

3.3 Course development

As will be described in Section 0, the PATC funding available from PRACE is much less than the total cost of developing and delivering HPC training courses. This is not at all surprising as it is much more cost effective for PRACE to buy into an existing training programme than to develop one from scratch: being an existing centre of excellence for HPC training was a key criterion in selecting the PATCs in the first place. However, the current funding level means that centres are only really able to deliver additional course runs comprising material that they already have, or that they are already developing under another funding scheme (e.g. as part of their national service provision activities). Although PATCs can decide to pay for courses from external suppliers, this is only cost-effective for one-off courses and ceases to be attractive if the course is to be run several times.

A valuable asset to the PATCs would be dedicated course development effort, which would be deployed whenever a future training need was identified so that appropriate course material can be developed. Specific examples might be the emergence of a new accelerator technology of wide applicability, or a new programming model of potential benefit at Exascale. These areas might have been identified by other PRACE work packages, for example from the prototype or pre-commercial procurement activities, and there needs to be a way for this to feed back into the training programme.

This would be extremely valuable as it would be a one-off investment that would benefit the whole of PRACE in the long term. Again there are potential difficulties with assigning funding to partners which is appropriate to their training commitments, but these could be addressed to some extent by funding more staff PMs specifically associated with the PATCs – see Section 6 for further discussion.

3.4 Dissemination

The core PATC curriculum is well presented on the training portal, with information available across all centres in a clear and consistent format. Due to data protection issues, there were some teething problems with accessing appropriate PRACE mailing lists but these appear to have been overcome and a regular bulletin advertising all upcoming courses is sent out monthly to 2260 people on the *prace-training-announce* mailing list (this number increases with time). The list comprises all people who have attended PATC courses and PRACE seasonal schools, and has recently been opened up to enable postings from individual PATCs. In addition to this centralised publicity, all PATCs will have their own contact lists where they can advertise their own courses and/or forward the centralised emails.

However, there are still two main issues regarding dissemination:

- a. Given the attendance statistics from non-PATC countries, we need to make more of an effort to target these users; this may be difficult with a mailing list built mainly from those who have already attended PRACE events.
- b. To act as genuine hubs of HPC training, it would be best to advertise all relevant events taking place at PATC (and non-PATC) sites. This is not completely straightforward as we have to be careful not to bombard users with too much information, and we also have less control over the content or quality of courses

outside the PATC curriculum. However, it would be useful to disseminate the availability of a wider range of courses than the curriculum, if only to increase the visibility of the training portal.

A more active role in dissemination of the HPC training available across the whole of Europe can only be beneficial in terms of the long-term sustainability of the PATCs.

3.5 Industry

The current statistics show relatively low attendance (9% of the total) from non-academic users. This is perhaps not surprising as the original remit of the PATCs was largely an academic one, with explicit industry engagement coming later through the ideas for industrial PATCs. It is also harder to target potential industry users as they are generally not existing users of the PRACE or national HPC systems. The industrial need has been addressed by the existing PATCs running courses targeted at industry as opposed to having a separate industrial PATC centre; this approach was strongly endorsed by the curriculum review panel to help foster collaborations with academia. In particular, it was stressed that having both industry and academic attendees in the same course could be a first step in having these two communities talk to one another. However, it remains to be seen how successful this approach is in terms of attracting industrial attendees, especially as their requirements may be substantially different from academic users. For example, industrial users are more likely to use “canned” software packages, which are often large commercial packages. They may also require more basic training on the benefits that HPC can bring to them, knowledge which is usually taken for granted with the academic community, and such basic training was seen as outside the remit of the PATCs prior to the recent funding for targeted industrial courses.

A different direction, that has already been successfully explored during seasonal schools and PATC courses, is for ISVs who specialise in HPC tools (e.g. Allinea and CAPS Enterprise) to deliver lectures as part of training courses. This could be extended to ISVs interested in specific fields such as CFD or structural mechanics, and this is currently being explored by the PATCs.

In terms of outreach to new industrial users, the new PRACE SHAPE programme [8] offers an ideal route for understanding their training needs. SHAPE proposes collaborating with the PATCs at one particular step of a typical scenario: “training phase – exploring the options that provides the PATC curriculum ...” [8]. Although the SHAPE pilot project completes too late for its results to be taken into account for the initial phase of industry-focused PATC courses, SHAPE will clearly play a key role in the curriculum for future industrial training.

Although charging fees from non-academic attendees is a potential source of revenue, there are some practical and legal issues associated with this which vary from country to country. These are discussed in Section 0. Interestingly, SHAPE does not propose directly charging for its services: “SHAPE should not charge the SME directly: rather it should foster the creation of bilateral collaborations between the research laboratory of the expert and the SMEs” [8].

4 Future opportunities

In this section we summarise the potential for the PATCs to increase their impact on HPC training across the EU by further engaging with user communities and other EU projects.

This section does not address financial sustainability. Rather, it discusses how the PATCs can become more sustainable in the sense that they address the HPC training needs across a widening range of scientific areas. This helps sustainability as it generates a self-sustaining demand for the PATC training programmes as they come to underpin computational research programmes across the EU as a whole.

4.1 Tier-1 optional programme

PRACE-3IP currently also offers access on Tier-1 machines across Europe in addition to the flagship PRACE Tier-0 systems. Tier-1 users can benefit enormously from appropriate training, enabling them to make more efficient use of the systems and help them move up a level to Tier-0. It is important that a sustainable PATC programme addresses their needs. Although there might be little need for training courses specific to Tier-1 users, catering for their requirements would have an impact on the number of courses and balance of the curriculum as a whole (e.g. more runs of the less advanced courses).

4.2 Transnational access programmes

Although there are not currently any concrete plans for a successor to HPC Europa, there is a strong desire to look for EU funding from upcoming calls. The PATCs should aim to be a part of any such bid as they are the best way to integrate HPC training into such a visitor programme. There would obviously not be a 100% overlap between the PATC sites and the centres offering transnational access, but the geographical distribution of the PATCs should enable us easily to satisfy the training requirements of any European centres.

4.3 HPC communities

It is a clear sign of the fact that HPC is becoming a more mature field that computational scientists have started to form large communities around established software packages, much as experimentalists form communities around large-scale experimental facilities such as CERN, ITER and the ESRF. It is therefore essential that the PATCs address the needs of these HPC communities. For the package developers, this means ensuring that their requirements are taken into account when drawing up the curriculum of advanced courses. However, there are typically many more users than developers so it is essential also to disseminate best practice on how to configure and run popular packages efficiently. As this knowledge resides with the packages developers and expert users, this is best achieved by the PATCs operating as genuine training hubs, facilitating and supporting training courses provided by and for the communities themselves. Although HPC communities generally recognise the importance of training, they often have neither a remit nor funding to provide it. As a result, relatively modest support from the PATCs (administration, registration, access to training facilities, speaker travel expenses etc.) can make a large impact.

4.4 Other training initiatives

Even after little over a year of operation, the PATCs have started to collaborate with other training initiatives. For example, the EUDAT project is delivering two data-related courses in 2013/14; the EU-funded HiPEAC network of excellence is delivering training on parallel programming at BSC; the UK-funded SPRINT project is teaching parallel analysis of post-

genomic data at EPCC. In the wider training programme, PRACE collaborates with Japan and the US XSEDE project through the yearly joint International Summer School which alternates location between Europe and the US.

However, there are a wide range of other programmes with whom the PATCs could usefully collaborate given appropriate resources. Both EESI and ETP4HPC have interests in training, and the links with XSEDE could be expanded beyond a single yearly event, e.g. by sharing training sessions electronically or exchange of speakers and/or material.

4.5 Interactions with university education

Universities are clearly the most sustainable form of training provider, many having existed for several centuries. However, there is a clear distinction between the training provided by PRACE and the education provided by the university sector. This is not so much in terms of course content as many (though not all) of the PATC courses are of university level; for example, portions of EPCC's PATC training material are also delivered (often by the same trainers) as part of the University of Edinburgh's MSc in HPC. The major differences are: a university course is formally accredited by some educational body; there will be some kind of formal assessment; successful students receive credits that count towards a recognised degree qualification.

One of the main issues identified with HPC education is that it starts too late (e.g. at postgraduate level) and should be integrated into undergraduate courses. As mentioned previously, the PRACE training survey [4] identified that only 20% of respondents had received training in parallel programming at university. However, given the many complexities of accreditation of lecturers, course content and assessment (which may vary from university to university, let alone country to country) it seems very unlikely that PATCs could deliver significant amounts of credit-bearing education for universities, except in particular circumstances e.g. where a PATC trainer is already a university lecturer.

Despite this, there are still opportunities to extend PATC activities to the university sector, though perhaps not at undergraduate level. Many PhD programmes require students to attend a certain number of courses to expand their knowledge outside of their core research area, but do not require that the courses are formally assessed; all that is required is that the courses are given some number of agreed credits and a record of student participation. This arrangement is already in operation for some specific courses at BSC, CINECA and EPCC. It would be good to extend this as widely as possible, ideally in close collaboration with existing HPC communities such as the ITNs. It should be noted that graduate students do currently attend PATC courses and form an important part of the training cohort. As part of an upcoming PRACE-3IP WP4 deliverable, *D4.4 Training Collaboration*, some relevant ITNs have already been contacted. Even at this initial stage it is clear that there is a significant demand for HPC training, but its content varies significantly e.g. standard HPC courses such as OpenMP and GPU programming for QCD and Financial communities respectively, compared to much more domain-specific training required for bioinformatics communities, e.g. how to use HPC for large scale genetic sequencing.

Although PATC involvement in a separate postgraduate Masters programme might seem like a possible option, in practice it is almost certainly infeasible. For example, EPCC has experience of proposing an Erasmus Mundus HPC Masters programme, which comprised integrating existing and already accredited MSc courses across universities in four countries (UK, Germany, Sweden and Ireland). This apparently simple integration was in fact extremely complex from an administrative point of view. Attempting to create a Masters programme from the PATC curriculum is much more complicated, and would very probably not be possible in practice.

5 Funding

This section covers the current funding model and discusses the breakdown of total costs for delivering HPC training.

This report concerns the sustainability of the PATCs in terms of both demand for their training services and the supply of the courses. It is essential to recognise that, entirely separate from their PATC activities, HPC training is already sustainable at each PATC host. To become a PATC, each centre had to demonstrate that they had a strong track record in delivering training and a wide portfolio of HPC courses. For this to be true, there had to already be a sustainable funding model for training including the substantial costs associated with course development and maintenance. Currently, PATC funding only covers some of the additional costs associated with additional runs of these existing courses, or buying in training from another supplier. It is essential to understand the full costs of training if the PATCs are ever to move beyond this model, e.g. to develop PRACE-specific training in response to user requirements and to become “a visible and important part of the electronic research infrastructure in Europe“ [1].

5.1 Current funding model

The current funding model for the PATCs was set out in [1]. It was estimated that, for a typical course, the running costs would be around 100€ per participant, with an additional 1000€ to 1500€ required for any external speakers. Estimated attendance of 25 participants per course (the actual average was in fact approximately 25 per course-day) resulted in a budget of 30000€ per year; the PATCs were actually allocated 45000€ each to cover the initial 18 months. For some PATCs, project PMs were available to cover the work effort and associated costs of all PRACE personnel contributing to the PATC activities; other PATCs supplemented project PMs with in-kind contributions of work effort towards PATC activities. Non-PRACE personnel, i.e. external trainers, were to be compensated with an honorarium paid from the budget provided to each PATC. All courses are currently provided free of charge so there is no income from attendees.

5.2 Breakdown of costs

The total costs of running training can be broken down into a number of areas:

- a. Course development
- b. Course maintenance
- c. Facilities (e.g. room, HPC access etc.)
- d. Trainer delivery time (preparation and lecturing/demonstrating)
- e. Administration (OMB activities, publicity and registration)
- f. Trainee costs (catering etc.)

Rather than trying to estimate these costs individually, it is more instructive to have an independent estimate of the total. If we could identify an HPC centre which only did training then this would be very simple: we could divide the total annual turnover of the centre (which includes all costs) and divide by the number of course-days delivered per year. However, HPC training almost exclusively operates within the much wider context of a centre's activities so it is difficult to separate the costs out.

The UK university sector gives a test case for this as it recently started to charge full fees for students, amounting to £9000 (around 11000€) per year. In science and engineering, a student will receive around 400 contact hours per year, which would equate to around 60 days of

training if delivered in the intensive format of the PATC courses. This equates to 180€ per course-day.

To make a direct comparison with the PATC costs is quite difficult as these fees also include costs associated with assessment, but do not include catering. Per-trainee costs clearly vary with class size, but universities are able to achieve much greater economies of scale with large undergraduate classes in the hundreds. Course development and maintenance is likely to be less for many core university courses whose content will be fairly static from year to year, and can be based on well-established curricula and high-quality textbooks. This is not true for most of the HPC courses run by the PATCs, especially as their aim is to target expert users of large systems. Taken at face value, this calculation does give a figure of 4500€ per course-day (using the same class size of 25) which would mean an annual PATC budget of around 130000€ (excluding catering) per centre.

It is important to recognise that this is very much a lower bound on the actual costs for the PATC courses. As mentioned above, universities have significant economies of scale compared to the PATC curriculum. HPC is a rapidly evolving subject, particularly at the leading-edge which is the main focus of PRACE, so substantially more course maintenance and development work will need to be done by the PATCs. A commonly quoted figure is that it takes ten hours to develop a new (one-hour) lecture. This again seems an underestimate: it does not seem credible that someone could design and develop a day's HPC training of three lectures and three practical sessions (six hour) in only two weeks. The novel nature of HPC also means it is often not possible to draw on standard examples and solutions from the literature.

In summary, it would appear that although the explicit PATC budget covers items (e) and (f) above (and some funding for (d) in terms of PRACE PMs), the centres are finding funding for items (a) – (d) that amounts to around three times this amount. In other words, the in-kind contribution is currently of the order of 75%. Although this shows that the PATCs in their current form are excellent value for money for PRACE, it does mean there is little flexibility to extend the role of the PATCs without extra funding.

5.3 Flexibility of the funding model

To enable the PATCs to be more responsive to user needs, it would be beneficial if there were more flexibility in the funding model. Giving each PATC a fixed amount means it is much more difficult to cope with changing circumstances. Although the amounts can be varied via contract amendments, this seems a very cumbersome approach for relatively small amounts of money. It would be good to investigate if there were an alternative model where a fraction of the funding could be retained in a central PATC pool, to be distributed to the individual centres as required.

Equally, it would be beneficial to have more flexibility in the way the money could be spent, particularly in the way it is split between centre staff and non-staff costs. For example, one PATC might want to use its own staff to develop material, whereas another might decide that staff from a non-PATC centre have the required training expertise and so would prefer to outsource its development. The strict division that currently exists between staff and non-staff costs, and the difficulty of transferring funding between partners, both limit flexibility at present.

6 Scenarios

Based on the discussions of the previous sections, we outline here a number of possible scenarios for continuing the operation of the PATCs beyond end of PRACE-3IP. The pros, cons and ramifications of these scenarios are summarised where appropriate in Section 7 for easy reference. Unless stated otherwise, the assumption is that the same number of PATCs would be operational and delivering a core curriculum of the same size as the current curriculum. We make few assumptions about the actual sources of future funding (which are unclear at present); rather we indicate the amount of funding that would be required. These scenarios will be proposed to the PRACE association as valuable input to the on-going strategy discussion for PRACE 2.0.

6.1 Minimal scenario

It is instructive to consider the minimum funding that would be required to continue the core PATC activity of delivering the joint curriculum. Note that we do not consider this to be a truly sustainable option as it does not address any of the issues of increasing the range and accessibility of PATC training, nor does it address the sustainability of the other training-related activities in WP4 (and WP3). However, such a scenario might potentially be required to hold the PATC infrastructure together to bridge a temporary funding shortfall.

We estimate that the minimal budget per PATC per year would be 9PMs + 25K€ This would cover staff time for administration and OMB participation (2PMs) and course delivery (7PMs). It would also cover a basic management travel budget of 2.5K€ and per-attendee costs such as catering of 22.5K€, this latter figure could potentially be reduced substantially by charging for attendance (see below) but this would almost certainly reduce the number of attendees. On top of these per-PATC costs, the OMB coordination role requires an additional 3PMs and central production of promotional material 21K€

6.2 Sustainable scenarios

Having outlined the bare minimum scenario above, we now discuss the ways that the issues previously discussed in Sections 0 – 5 could be addressed and sustained in the future, and outline the funding implications. All funding is quoted per year assuming the current number of PATCs; all figures are estimates.

6.2.1 *Course development*

PRACE must have an ambition of developing new course content in addition to buying-in to existing training material of the PATC sites. For this there needs to be additional PMs for course development. Ideally this would be a central resource, allocated by the OMB based on requirements. For example, a particular centre could be funded to develop material to engage with a new HPC community. If such material were to be developed with the aim of potentially being delivered by several PATCs, some more effort would be required than for a standard course e.g. to write additional documentation and trainer's notes so that it can easily be delivered by other training staff.

We would propose an annual budget of 6PMs for course development. The OMB proposal for an annual curriculum would also include new courses to be developed and run (at least once) in the coming academic year, including the target audience, learning outcomes and effort required. This would not be restricted to a PATC site writing new material. For example it could include putting together a new community-specific course by surveying existing

trainers and/or material, supplemented with additional material developed by the PATC (less effort than developing from scratch but still a sizeable undertaking). Or it could be a course developed or customised by a non-PATC site, which would be a good way of engaging the wider PRACE training community.

6.2.2 *Trainer mobility*

To promote the collaboration in training activities between PRACE members and to fully benefit from the expertise of all PRACE experts, travel costs of PRACE lecturers should be partly or fully covered. This would allow the exchange of lecturers, fostering of collaboration, and transfer of knowledge among PRACE staff. Hosting of PATC courses in non-PATC countries would provide an opportunity to transfer training skills to a less experienced training centre in the form of giving a practical example of running a training event and act as a “train the trainers” event for local centre staff.

An annual travel budget of 8K€ per PATC would cover sufficient travel and accommodation for PRACE lecturers to visit PATC sites and for PATCs to run courses at other PRACE sites. It would also cover attendance costs for OMB and face-to-face meetings. Following the successful “train the trainers” model already employed by the UK’s SSI (see Section 3.1), preference for remote course locations would be given to PRACE sites that demonstrated the most commitment to supporting the initial training event (including colocation with related events) and to running the course themselves in the future.

6.2.3 *Trainee mobility*

As described in Section 3.1, the ability of PATCs to draw attendees from abroad has been somewhat limited. To truly serve all Europeans, also those coming from a non-PATC country, ways to promote trainee mobility should be explored. An obvious way to promote mobility would be for the PATCs to offer travel grants for participants coming from abroad. The actual costs of travel are highly case dependent and therefore a more simplified model than full reimbursement should be sought. A bursary in the order of 200€ would partly cover housing and travel costs making it easier for people to attend courses abroad. The bursary could be either against receipts of actual costs or as a flat sum. National legislation may require in some countries the additional administrative burden of requiring receipts, but a flat sum given to all applicants would be preferable from the point of view of the PATC, especially for the small travel grant outlined above. Issues of prioritisation of applicants (e.g. depending on their country of residence) would require careful investigation and any selection process would have to be fair and transparent. If needed, the amount of travel grants awarded can be easily scaled down or up either by adjusting the maximum allowance of a travel grant or by limiting the number of people awarded one. We estimate that something in the region of 60K€ and an additional 3PM of administrative effort, would enable an impact to be made in this area. This would enable us to fund around four students per course at the level of 200€ each, or fewer students with correspondingly larger bursaries.

6.2.4 *Seasonal schools*

As previously mentioned, the seasonal schools in PRACE-2IP and PRACE-3IP have been very successful and have complemented the PATC curriculum in both content and location. The Curricula Advisory Panel commented on their role in increasing the accessibility of PRACE training, and they provide excellent opportunities for dissemination of PRACE to new communities.

In order to maintain the schools, and continue full coordination with the PATC curriculum, they could be coordinated in future by the PATC OMB (with additional advice from other PRACE partners). Unless there are specific reasons (e.g. colocation with some other event) the policy should be continued of rotating them round non-PATC countries. Maintaining the current model would require an annual budget of 60K€ (for four schools per year) plus around 8PMs (2PM per school) of admin effort. The location and focus of all four schools would form part of the annual PATC curriculum proposal.

6.2.5 *International Summer School*

The “International Summer School on HPC Challenges in Computational Sciences” is a very important and highly visible international collaboration for PRACE. Since 2010, the school has received co-funding annually from partners in Europe (DEISA, PRACE) and the US (Teragrid, XSEDE). In 2013, RIKEN from Japan has also joined the collaboration and contributed funding. The school attracts some of the most talented researchers from eligible countries and entry is highly competitive; there were more than 200 applications for 30 places reserved for Europe in 2013. The school invites leading scientists from multiple disciplines and HPC technologists to present, to teach and to mentor participants as part of an intensive programme. The prestigious event has also attracted attention at the government level, where an Irish minister addressed the audience at the 2012 school in Dublin. There has been ongoing interest from organisations in other countries to join this collaboration (e.g. Canada, China).

European (PRACE) funding for this event has been committed as far as 2014 from PRACE-3IP. The natural way to continue it beyond PRACE-3IP is the same as for the seasonal schools, i.e. to have it coordinated by the OMB with appropriate additional advice. Again, this minimises the possibility of clashes with other events and maximises complementarity with the other PRACE training activities and resources. An average of 3PMs of effort is required per year. Organisational effort varies depending on the location of the school, i.e. in Europe, the US, or potentially elsewhere as new partners join.

Current costs are around 45K€ per year for around 30 European students. This could potentially be reduced, e.g. by charging a registration fee of around 500€ or by waiving travel subsidies for participants. Any more reduction in funding is likely to significantly affect the ability of many students to attend and ultimately resulting in a European exit from the collaboration. Given this, we would require a minimum of 30K€ per year to continue European involvement in the school.

6.2.6 *Summer of HPC*

The Summer of HPC (SoHPC) programme, started in PRACE-3IP, has surpassed all its targets so far in terms of student interest and recruitment, and all the signs are that it will be a great success. It had attracted 189 students to apply for the programme with significant dissemination effort through social media (e.g. Facebook, Twitter). Having built up interest and momentum, it would be a missed opportunity not to take it forward beyond PRACE-3IP. The SoHPC activities have been very visible to the PATCs via the joint WP3 and WP4 meetings, which has already enabled us to schedule particular PATC courses to the benefit of students. The SoHPC has entirely its own funding for staff PMs and student costs, but it is still addresses the same community as PRACE training so it would be natural to continue it within the remit of the PATC OMB. Assuming it is continued in its current form, this would require an annual 8PMs of staff effort for dissemination and administration and 4PMs for student supervision (all currently provided by 3IP WP3), and 100K€ for travel and subsistence costs.

6.3 Additional scenarios

A number of the future options have little or no financial implications, or may actually reduce the funding required. However, some require additional investigation regarding implementation details.

6.3.1 *Charging attendees*

One relatively straightforward way of getting partial funding for the training is to charge fees from the participants. It is clear that this can be only a partial funding source, since charging fees that would cover full costs would raise them to commercial levels which would make courses inaccessible to the main target audience of academics. In the original PATC proposal it was stated that, if course fees were ever to be introduced, they “should be at all times affordable for academics of PRACE countries“ [1].

Because appropriate training is so crucial to efficient use of high-end HPC facilities, it is very important not to discourage people from attending. In general, academic training courses across Europe are provided free of charge to attendees, or with a modest fee when some funding is required to pay for specific per-attendee costs such as catering, printing course notes etc. In light of this, the maximum reasonable charge is estimated to be around the figure of 100€ per course (i.e. 30€ - 40€ per day) that was used as an input to the current PATC budget. This would cover only the bare minimum running costs mentioned above: additional funding for PMs would still be required to cover all other costs. Expenses such as PMs for running the courses, or for developing new courses, are simply too high to be funded from fees for academics.

Other than perhaps the need to provide additional training staff to cover practical sessions, the only PATC costs that scale directly with the number of attendees are indeed catering, printing etc. There is therefore some argument to be made for considering passing some of these on to the attendees, and it may help to reduce the number of “no-shows” (although this is not actually a current concern). This still gives each centre freedom in choosing what courses to run as they will not be financially disadvantaged for running advanced courses with a small audience (as they would be if all costs were recouped from attendance fees). Any attempt to recoup more than the per-attendee costs per course has serious ramifications: it would conflict with the principle of having a PATC curriculum based purely on user requirements as the choice of which courses each PATC chose to run would then be strongly financially constrained.

The disadvantage of this option is that it will discourage some people from attending. It should always be remembered that there is a real (but perhaps hidden) cost of *not* training users as lack of training leads to inefficient use of resources.

There is also the option of charging non-academic attendees a much more substantial fee, something which was considered but not implemented for the current PATCs. This is certainly an option, and could generate a modest income stream across all courses (which are all open to both academic and non-academic attendees alike). The most income would of course be generated from those courses specifically targeted at industry. However, this may be counterproductive as one of the main aims of these industry-specific courses is to engage new industrial partners, who will perhaps be less likely to attend if there is a substantial charge. As noted previously, PRACE’s own SHAPE outreach programme for SMEs will not be charging fees. Given the different financial rules and constraints across the PATCs, it will also be unlikely that a single policy can be adopted.

6.3.2 *Flexibility*

Although planning a full curriculum over a year in advance has many advantages, to address the problems presented in sections 3.1 and 3.2 there are also arguments for retaining some flexibility in course provision. We would propose, e.g., retaining 20% of the course-days unassigned at the initial curriculum planning stage, with topics and locations to be decided as the year progresses. This would still allow us to propose a stable core curriculum, but would increase the overall quality as training could be better tailored to changing requirements. All PATCs would still be committed to running 100% of their training days per year, and all training would have to be confirmed at least 3 months in advance to match the horizon of the regular PATC email digest.

We have noted in a number of places that the fixed allocation of funding to partners (such as travel budgets and staff PMs) can be problematic when the PATCs need to react to changing circumstances. This is further complicated by EC funding rules which require contract amendments to transfer funds between partners. Currently, this means we can use PATC funds to pay the expenses of a US speaker but not for the expenses of a speaker from another PRACE partner. If the OMB wishes to run a course at, or commission training from, another PRACE site it would be much simpler if that site could invoice the OMB directly. Whatever the source of funding for the PATCs, it would be very useful to be able to manage the funds across the PATC programme as a whole rather than on a strict per-PATC basis.

Combined with increased trainer mobility, these extra levels of flexibility will put the PATCs in a much better position to exploit the future opportunities described in Section 4.

6.3.3 *Training portal*

A unique feature of the PATC HPC training curriculum is that courses across all PATCs are managed centrally using the INDICO system on the training portal. The portal itself is also the repository for a variety of course materials. To maintain the PATC brand, it is essential that its operation is continued. This requires relatively small amounts of funding as much of the web admin (e.g., instantiating courses, entering course information, collecting feedback) is delegated to individual PATC coordinators. Ensuring the continuity of the portal itself is more a matter of good planning than one of funding.

7 Options

In Section 6 we explored various scenarios and the associated funding implications. Here we summarise the funding required and highlight the pros and cons of each option. All funding is given as the total per year across all PATCs (assuming the current number of PATCs). Where charging fees is an option we indicate the minimum funding based on the maximum reasonable fee. All figures are estimates. Options discussed previously that have no direct financial implications (e.g. more flexibility in funding mechanisms and curriculum planning, increased dissemination and outreach, etc.) are not presented here, but are still very important.

Key Decision		K€per annum	PMs per annum	Pros	Cons	Impact if NOT funded
1	Continue PATCs with the intended scope for best impact	484	89	Ability to provide a comprehensive training programme that benefits all European researchers at different levels.	May be seen as expensive.	Options to continue PATCs with more limited scope should be explored if budget is limited.
2	Continue PATCs with limited scope Baseline funding to maintain basic PATC operations (but not sustainable by itself)	171 (min. 36 if fees)	57	Maintains PATC network at minimal cost	Not sustainable long-term; no additional benefits such as outreach to new communities or other training activities such as seasonal schools.	HPC training continues but in fragmented per-country model; no central organisation; many PRACE partners suffer large reduction in advanced training provision.
(a)	+ Course development	0	+ 6	PRACE-specific course material in response to user requirements; higher quality courses; central repository of PRACE training material.	Requires flexible funding for PMs.	Significant loss of opportunity to provide value-add services.
(b)	+ Trainer mobility	+ 48	0	Wider audience; more training in non-PATC countries; promotes training for trainers.	Slight admin overhead for PATCs; increased time commitment from lecturers due to travel; more complicated financially	No off-site courses and hence reduction in the number of trainees from non-PATC sites.
(c)	+ Trainee mobility	+ 60	+ 3	Wider audience; increased attendance from non-PATC countries.	Increased admin overhead; must consider relative effectiveness compared to trainer mobility when setting funding levels.	Fewer attendees from non-PATC countries, i.e. those who could not source funds to travel to PATC courses.
(d)	+ Seasonal Schools	+ 60	+ 8	Continue successful activity; promote training in non-PATC countries; maintain effective PRACE dissemination to wider EU HPC community.	None (other than cost).	Goes against recommendation from external panel of experts; PATCs mostly serve researchers in own countries.
(e)	+ International HPC Summer School	+ 45 (min. 30 if fees)	+ 3	Continue involvement in successful and growing activity; maintain effective PRACE dissemination to worldwide HPC community; promotes overseas collaborations and career development of early stage researchers.	More expensive than seasonal schools.	European exit from an important ongoing global collaboration when other countries / continents are seeking to join.
(f)	+ Summer of HPC	+ 100	+ 12	Continue successful activity; will be easier to run after initial setup costs; potential for extensive PRACE dissemination to university students.	Requires additional staff for administration and technical supervision.	Ending an activity that had reached out to hundreds of European students through social media.
3	Do not continue PATC funding	0	0	No further funding required from PRACE	No PATC network	N/A. See Option 2 above.

Table 1: Summary of options

8 Summary

In this document we have addressed the issue of the continuity of the PRACE Advanced Training Centre in terms of both sustaining the demand and the supply for HPC training. The current PATCs are proving very successful, as evidenced by the positive feedback from course attendees and the recent external curriculum review. There are still several issues that could be addressed, and a much wider range of opportunities to expand the scope of the PATC activities both inside and outside the current PRACE project. All these opportunities are concerned with maintaining or increasing the quality, range and accessibility of the PRACE training programme across Europe and beyond. Having discussed various scenarios, we presented a list of options for various levels of PATC activities together with associated pros, cons and funding implications.