Findings and Recommendations of the Committee for Research Computing around MIT’s Use of the Massachusetts Green High Performance Computing Center (MGHPCC)

November 19, 2012

Executive Summary

The Committee for Research Computing (CRC) was formed as a standing committee in May 2012, for the purpose of providing advice and guidance to the VPR and to the IS&T Governing Committee on strategic issues related to research computing at MIT.

After meeting approximately monthly since July 2012 and conducting online and in-person interviews with various stakeholders in the MIT community, the CRC offers the following five recommendations:

1. MIT should limit its immediate focus to two use models; (1) a co-location capability, to be made available to the MIT HPC community as soon as possible and (2) a shared system capability that should be piloted first with a small set of users, with the intention of its being made available to the entire MIT HPC community in mid-2013. For planning purposes, a capacity ratio of 1:2 co-location: shared is recommended.

2. A direct-cost rack charge should be adopted in the range $1000-$2000 per rack per year for a modest level of end-user services. At the lower end of this range, these services should reflect the level and type of services provided to users of the Bates facility (c.f. Appendix D). The higher end could be justified based on additional systems support.

3. MIT should consider investing in a program to pilot a shared-use facility of five to ten racks of computing and storage equipment and some allocation (e.g. 2-3 FTE, c.f. Appendix C) of IT professionals to get the system up and running. We also recommend assembling a small cohort of early adopters to help work out bugs in operation and billing, before going “live” to the entire MIT community.

4. MIT should implement a policy of financing the installation or relocation of on-campus HPC equipment to the MGHPCC for an initial period of six to twelve months, in anticipation of realizing institutional savings that will offset these costs. A fixed-term waiver of direct costs to investigators for housing equipment at MGHPCC might also be useful for encouraging adoption.

5. MIT should create a new research computing position with some institutional budgetary support and joint reporting/oversight to the VPR and IS&T. The position would involve coordinating with administration and faculty to deploy useful new models for facilitating computational-based research in a way that (1) supports faculty and PI endeavors in all relevant areas of the Institute and (2) is financially sustainable and cost-effective.
High Performance Computing (HPC) refers to the use of computational resources to solve complex science, engineering and business problems using methods that are characterized by high bandwidth, low latency and very high operation rates. A consortium of MIT, Boston University, Harvard, Northeastern, and the University of Massachusetts system, with assistance from the Commonwealth of Massachusetts, EMC and Cisco, formed in 2009 to build and operate the Massachusetts Green High Performance Computing Center (MGHPCC), a new, 90000 sq. ft. off-campus facility in Holyoke, MA, with high speed data connections to the MIT campus. The new facility is designed to address current and future demands over the next 5-10 years for scientific computing, to leverage intellectual and infrastructural resources from the partner universities and to take advantage of lower power, space and cooling costs. The MGHPCC is expected to come online in Q1 2013. More information about the MGHPCC can be found at http://www.mghpcc.org.

The Committee for Research Computing (CRC) was formed as a standing committee in May 2012 by Vice President of Research (VPR) Claude Canizares, for the purpose of providing advice and guidance to the VPR and to the IS&T Governing Committee on strategic issues related to research computing at MIT. The CRC membership currently consists of Markus Buehler (CEE) Chris Hill (EAPS), Andrew Lo (Sloan), Terry Knight (Arch), Bob Redwine (Phys, co-chair), Greg Rutledge (ChE, co-chair), Bruce Tidor (BE, EECS), Karen Willcox (AA) and Nickolai Zeldovich (EECS). MIT IS&T Head Marilyn Smith is a member of the committee ex officio. One of the initial tasks of this committee is to provide guidance on the policies and practices for operation of MIT’s share of the MGHPCC.

Since July 2012, the CRC has met approximately monthly with the goals of (i) identifying the community of research computing users at MIT, (ii) understanding the current and future needs of this community for high performance computing, and (iii) identifying opportunities presented by the new MGHPCC facility that could help to meet these needs. In addition, the CRC has acquired information through the following sources (details are provided in Appendix B):

- Results of a broad survey sent to all faculty and principal investigators at MIT. A total of 319 responses were received.
- One-on-one interviews between individual committee members and a self-identified sample of interested faculty and principal investigators.
- One-on-one interviews with two “large scale” users in CSAIL and Sloan
- Internal committee discussions.
- Discussions between committee members and IS&T head Marilyn Smith and her staff and with VPR Claude Canizares.

This document summarizes the CRC’s findings and recommendations. Related appendices provide additional material explaining recommendations. A preliminary report was given orally to the IS&T Governing Committee in September. Overall, the recommendations advocate a set of actions and investments that the CRC believes are
warranted by the availability of the MGHPCC facility. We believe our recommendations would benefit HPC research in many areas and across many DLCs, as well as reduce pressure on premium campus space and on campus operating costs.

Findings and Recommendations

(1) MGHPCC use models:

Findings: Historically, research computing at MIT has been the responsibility of PIs and their staff. In addition to numerous single-PI clusters scattered around the MIT campus, often occupying prime research space, there are currently two co-location facilities at MIT, the W91 facility on campus and the Bates facility in Middleton, Mass. The physical facility and services offered by MGHPCC provide for up to 68 racks initially, and can simultaneously accommodate use models that range from an individual investigator co-location service to an Institute wide shared service. The CRC survey and interviews found that while most current MIT efforts are of a co-location nature there is significant interest in other use models (buy-in, dedicated and shared) (see Appendix A for definitions of these terms).

A “one-size fits all” approach is not desirable. The MIT plans for MGHPCC should envision supporting a mix of co-location, buy-in, dedicated and shared systems. This mix reflects a similar palette of options to be supported by Boston University at the MGHPCC. MIT’s plans should allow for the balance and mix between all of these use models to evolve over time. From the survey and interviews conducted by the CRC over the past few months, it appears that co-location and shared systems are likely to be of the most immediate interest.

Recommendation: The CRC recommends that planning focus immediately on two use models; (1) a co-location capability, to be made available to the MIT HPC community as soon as possible and (2) a shared system capability that should be piloted first with a small set of users, with the intention of its being made available to the entire MIT HPC community in mid-2103. For planning purposes, a capacity ratio of 1:2 co-location: shared is recommended.

(2) Service and financial models for co-location use:

Findings: The MGHPCC plans to bill MIT on a rack-by-rack basis for energy and for fixed operating costs each month (see Appendix C for a detailed accounting of these charges). Some of these charges are ultimately recoverable from the F&A indirect cost pool. Other charges are not allowable for recovery and will need to be met from some combination of Institute funds and allowable (and acceptable) direct charges to research grants. The MGHPCC bill includes items such as liability insurance, audit and legal services that are typically not direct charged at other co-location facilities maintained by MIT (Bates, W91).
Requirements and expectations for levels of service provided and user fees vary widely among MIT’s research computing community. For many users, it is not practical or efficient to delegate common system administration tasks to individual members within each research group. In general, the CRC’s perception is that reliable service and support are more important to the majority of MIT’s users than low fees, but that the services provided should be visible to the user and clearly value-added. An opportunity exists for economies of scale in services provided by the MGHPCC. The service model at Bates—where tenants have shared access to an on-site technical employee who can carry out small tasks on the tenant’s behalf—appears to work well and could be replicated at the MGHPCC. This level of service limits the need for tenants to visit the Bates location for minor incidents and minor physical adjustments to systems. Tenants are still responsible for planning and execution of major physical tasks (see Appendix D for a description of services provided at Bates). The fees charged to users should be competitive with those currently charged by W91 and Bates, taking into consideration the additional concerns and inconvenience associated with the more remote location of the MGHPCC.

**Recommendation:** The CRC recommends adopting a direct-cost rack charge in the range $1000-$2000 per rack per year for a modest level of end-user services. At the lower end of this range, these services should reflect the level and type of services provided to users of the Bates facility (c.f. Appendix D). The higher end could be justified based on additional systems support.

(3) Service and financial models for a shared system:

**Findings:** Peer institutions around the US, including partner universities in the MGHPCC project, are considering approaches to research computing that allow investigators to pool resources and target economies of scale. The MGHPCC offers the rare opportunity to explore a buy-in and/or shared approach to pool HPC resources for individual users and small groups of users at MIT and to deliver HPC capacity as needed. Proponents of the buy-in and shared approaches cite potential economies of scale and productivity benefits.

Nearly three-quarters of survey respondents at MIT indicated an interest in purchasing HPC resources on an as-needed basis from an installed facility. This appears to the CRC to represent a significant shift in recent years in how high performance computing is perceived and used at MIT. Increasingly, research groups that would not previously have considered themselves to be users of high performance computing are now using computing as an integral part of their research activities. Many of these researchers would prefer a responsive, well-run and cost effective high-performance computing service to owning and managing their own equipment.

MIT does not currently have experience with a broad-based shared user facility in high performance computing. Facilities such as the one operated by CSAIL offer a model for operation of a shared user facility. However, the CRC anticipates that there will be a substantial learning curve in setting up such a facility and in developing the user base for it, from queue management and load balancing to accommodating specialized user needs.
There are also questions outstanding about how to fix fees for different types of use. However, commercially available “cloud” service providers such as Amazon’s Elastic Cloud offer some guidance in how such fees might be structured. The fees charged for shared use should be substantially less than those charged by commercial providers like Amazon, while data should be at least as secure. An initial cost analysis suggests this is indeed possible.

**Recommendations:** The CRC recommends that the MIT administration invest in a program to pilot a shared-use facility of five to ten racks of computing and storage equipment and some allocation (e.g. 2-3 FTE, c.f. Appendix C) of IT professionals to get the system up and running. We also recommend assembling a small cohort of early adopters to help work out bugs in operation and billing, before going “live” to the entire MIT community. Early adopters should be solicited from across the Institute, but likely candidates include newly arrived junior faculty, existing W91 tenants and DLCs interested in re-purposing use of prime on-campus space. Targets for pricing, access, operations and capabilities should be identified that make the service more useful to research than services from external cloud providers.

**(4) Encouraging adoption:**

**Findings:** The MGHPCC facility is a new facility, and in its early stages the facility will be learning how to operate effectively. This, plus anxiety about housing equipment remotely and uncertainty about fee structure, discourages PIs from considering the facility until they see some tangible examples of research value. Seeding the MGHPCC with some upfront investment to generate the user data and anecdotal support for the facility appears warranted. Housing computing off-campus results in institutional savings around power efficiency, space utilization and facilities costs on campus. The main beneficiaries are those who work at the DLC level or higher, where the savings can help DLCs free up space, reduce pressure on the energy and facilities maintenance portion of the indirect cost rate (Appendix C examines some of these items) and, importantly, provide more main campus space for core research and teaching activities. A number of these savings are not directly visible to individual faculty and PI’s, who pay no direct costs for housing computers in prime on-campus real estate (except those using W91). However, individual faculty and PI’s do appreciate the quality of space for housing computing, and are motivated to seek more secure, reliable and well-supported space such as that offered by the MGHPCC. The financial analysis provided in Appendix C suggests that the potential for Institutional savings that could be realized by moving equipment from W91 would more than offset the fees currently charged to users of that facility.

**Recommendations:** The CRC recommends that MIT implement a policy of financing the installation or relocation of on-campus HPC equipment to the MGHPCC for an initial period of six to twelve months, in anticipation of realizing institutional savings that will
offset these costs. MIT may further implement a fixed-term waiver of direct costs to investigators for housing equipment at MGHPCC, to encourage adoption.

(5) Governance and developing sustainable services:

Findings: Computing facilities play a major role in a growing number of research activities at MIT. Currently, most of these activities operate in isolation with individual or small groups of faculty. However, the computing landscape is continually evolving. It is likely that there are substantial benefits in cost savings and research productivity to be realized through a coherent institutional strategy around research computing and dissemination of information to the MIT research computing community. A central location such as the MGHPCC is a valuable Institutional resource for this purpose. In addition, many peer institutions have created committees to help ensure that faculty input is channeled into plans for directing such facilities so that they serve the research computing community. Based on the survey administered earlier this summer, there are over 200 faculty and PI’s at MIT who are interested in staying abreast of developments in the HPC landscape at MIT, and the MGHPCC in particular.

Recommendations: The CRC recommends that MIT create a new research computing position with some institutional budgetary support and joint reporting/oversight to the VPR and IS&T. The job description would be to deploy (in coordination with administration and faculty) useful new models for facilitating computational-based research in a way that (1) supports faculty and PI endeavors in all relevant areas of the Institute and (2) is financially sustainable and cost-effective. A first task would be to further develop the financial and technical details of the CRC recommended shared system pilot program and to bring the pilot program online. An additional role of the position would be to take steps to increase the level of awareness among the MIT research computing community about existing facilities and capabilities, and to coordinate opportunities to leverage resources with partner institutions at the MGHPCC. Lastly, the CRC recommends that MIT create a faculty oversight committee to monitor responsiveness of the MGHPCC to the evolving research needs of MIT HPC users. Oversight could be provided by the CRC as part of its overall mandate, but a dedicated sub-group may be a wise addition.
Appendix A: Definition of terms.
Terms used for different use models are based on definitions developed by the MGHPCC project.

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
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<tbody>
<tr>
<td>Shared system</td>
<td>A shared system refers to a model in which equipment is acquired with a significant institute contribution. Operational costs and equipment renewal costs are recovered through a mix of institutional support and direct charges to research grants based on a metered use algorithm.</td>
</tr>
<tr>
<td>Buy-in program</td>
<td>A buy-in program is a model in which researchers acquire additional, somewhat standardized hardware to support their individual research projects. The additional resources are integrated into a single facility and managed centrally. The owners of the equipment are given pre-emptive priority access while any excess capacity is returned to a pool for general, shared use.</td>
</tr>
<tr>
<td>Dedicated service</td>
<td>Dedicated service refers to a specialized resource that does not fit within the co-location service parameters. Dedicated service activities are charged according to a custom formula for each case.</td>
</tr>
<tr>
<td>Co-location service</td>
<td>A co-location service is a model in which researchers acquire hardware and uses MGHPCC rack space, power, cooling and long-haul network. A per rack direct charge is passed back to co-location users.</td>
</tr>
</tbody>
</table>
Appendix B: Summary of survey and interview questions and results.

To gain an understanding of the scope and membership of the MIT research computing community and to gauge current and future interests in high-performance computing among faculty and principal investigators, the CRC (with help from Jag Patel in the Provost’s Office) conducted an email survey that was sent to all faculty and principal investigators at MIT. This community is the one that drives sponsored research at MIT, so their thinking is most relevant to guiding current and future expectations for high performance computing. The email survey was short and designed to distinguish broad levels of interest, without regard to magnitude of use. Survey respondents were asked 6 questions as well as being asked to provide any other comments. Some highlights from the survey are summarized below:

(1) The survey elicited 319 responses.
(2) 230 respondents indicated they were interested in further updates.
(3) More than 50% of respondents interested in HPC (by number of people) were interested in a service they could buy into.
(4) There was significant interest in service models that addressed basic operations and systems administration activities.
(5) There was significantly less interest in applications level services.
(6) Nearly all the survey comments were constructive and wide-ranging. There were more than 80 of these and, although harder to summarize, they were instrumental in guiding the CRC recommendations on where to focus effort.

Distribution across Schools
There were respondents from every school within MIT who indicated that they are interested in further updates. Figure 1 shows how the interest in high-performance computing is distributed across campus by building. For each building a count of the respondents interested in further updates is given. The Schools of Science and Engineering accounted for about 75% of respondents interested in further updates, but there are 25% of interested respondents outside these schools.
Distribution of locations, by campus building address, of survey respondents

Figure 1 The picture shows the number of faculty and principal investigators in different campus building locations who indicated that they had interest in further updates to the CRC survey on high-performance computing interest.
A list of the survey questions and summary of responses, broken down by School is provided below. Courtesy of the Office of Institutional Research.

One-on-one interviews
In addition to the survey, the CRC employed one-on-one interviews to solicit more detailed input from (i) survey respondents who expressed an interest in knowing more about the MGHPCC and identified themselves as willing to be interviewed about their HPC activities, and (ii) selected representatives of “large use” facilities already existing on campus (CSAIL, Sloan). The CRC members conducted about 20 interviews. The results from these interviews confirmed interest in a well-run, responsive shared system.
model in addition to a co-location capability. The interview responses reiterated the notion that (1) any fee should include services that are visible to the PI paying the fee, and (2) there is an expectation that many of the less visible costs should somehow be part of the support provided by the Institute to investigators. The interviews included questions around future growth plans. Several interviewees expressed the desire to grow their capabilities, but precise schedules and demand forecasts were mostly linked to funding opportunities that were uncertain.
Appendix C: MGHPCCC financial details.

Financial Overview

Starting January 2013 the MGHPCCC will be invoicing MIT for its share of the facility total operating costs. This section describes the origin and estimated amounts of these operating costs. Financial considerations associated with recovery and depreciation of the building investments are separate from operating costs and have not been considered by the CRC.

The MGHPCCC project is a joint activity with four other partner universities. In effect, each partner has claim to one-fifth of the facility. The estimated bills to MIT described below represent this one-fifth split. The MGHPCCC base invoice will have at least two elements. One element is based on energy consumption. This element will vary according to actual energy and cooling charges for MIT equipment housed at MGHPCCC. A second element is a set of fixed operating costs. These are independent of facility utilization. The items included in fixed operating cost include building maintenance costs, support staff and executive staff compensation, items associated with administrative, legal, audit and insurance expenses and long-haul networking costs. The MGHPCCC also allows for a third set of charges that are fee-for-service based. These are services that MGHPCCC customers (such as MIT) can request on an as-needed basis. Charges for these services will be included in the MGHPCCC invoice only as they are incurred.

Estimating MGHPCCC bill amounts

Charges for certain items are still being finalized, so numerical amounts are currently based on estimates provided by the MGHPCCC team. Energy demand will also vary over the life of the project. The tables below provide guides for both the total facility costs and per rack equivalent costs. MIT will have access to 68 racks within the facility.

(1) Estimated MGHPCCC energy costs table

<table>
<thead>
<tr>
<th>Assumed electricity rate</th>
<th>$0.0839/KW/H</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average power use per rack (MGHPCC limit)</td>
<td>14KW</td>
</tr>
<tr>
<td>Energy cost for average rack @ PUE 1.3</td>
<td></td>
</tr>
<tr>
<td>Monthly</td>
<td>$1,120</td>
</tr>
<tr>
<td>Yearly</td>
<td>$13,500</td>
</tr>
<tr>
<td>Energy cost per year for 68 full racks</td>
<td>$980,000</td>
</tr>
</tbody>
</table>

The energy costs are 100% recoverable through institute F&A charges.

(2) Estimated MGHPCCC fixed operating costs/year table

| Total staff compensation (includes executive, outreach/collaboration and support activities). | $180,000 |
| Administrative costs (legal, accounting, insurance). | $104,000 |
| Financing and taxes (PILOT). | $84,000 |
| Building operations and maintenance. (F&A recoverable) | $198,000 |
| Network to campus. (F&A recoverable) | $67,000 |
Contingency. | $50,000
---|---
Annual total fixed operating costs (incl. contingency) | $683,000
Total per rack (@68 racks) | Monthly | $840  
 | Yearly | $10,100
Total per rack (@68 racks) after F&A recovery. | Monthly | $515  
 | Yearly | $6,150

Some portion of the fixed operating cost is recoverable through F&A charges – provided the MGHPCC space is in use for research.

Invoice amounts in context
In making recommendations the CRC considered several aspects related to billing and finances. We have noted some key points here, as the CRC found it useful to consider the MGHPCC invoice amounts not simply as bills to pay but also in relation to alternate paths.

1 In comparison with those incurred by typical campus space, energy costs at the MGHPCC are significantly lower. This reduction arises from a slightly higher on-campus marginal electricity rate and a more efficient cooling system at the MGHPCC. Typical cooling for on-campus computer rooms uses air conditioning in an open room. This type of cooling usually requires at least the same amount of energy going into cooling as goes to the computers. At the MGHPCC a conservative estimate for the cooling overhead is around 30% of the energy used by computers. Using these numbers we can compare the energy associated costs of a 14KW rack on campus with a rack at MGHPCC.

<table>
<thead>
<tr>
<th></th>
<th>Main campus rack</th>
<th>MGHPCC rack</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity rate ($/KW/H)</td>
<td>$0.1</td>
<td>$0.0839</td>
</tr>
<tr>
<td>Cooling overhead</td>
<td>100% (^1)</td>
<td>30%</td>
</tr>
<tr>
<td>Compute energy per rack (KW)</td>
<td>14</td>
<td>14</td>
</tr>
<tr>
<td>Total energy cost per year</td>
<td>$24,600</td>
<td>$13,500</td>
</tr>
<tr>
<td>Energy cost saving per year</td>
<td>$0</td>
<td>$11,100</td>
</tr>
</tbody>
</table>

Notably, the estimated energy saving cost for a 14KW rack ($11,100) is slightly larger than the MGHPCC yearly total fixed operating cost on a per rack basis ($10,100), and substantially larger than the MGHPCC yearly total fixed operating cost on a per rack basis after cost recovery ($6,150). It is also worth noting that an estimated 70% of the energy use at the MGHPCC is directly associated with non-fossil fuel, renewable generation. Locating equipment at MGHPCC will reduce the MIT carbon footprint.

2 An attractive (i.e. well-run, adequately supported and cost effective) off-campus location for computing could free up prime space on campus. The potential for freeing space for other uses ranges from individual rooms in departments to whole building lots such as W91. The CRC felt it would be challenging for our group to assign a hard dollar

\(^1\) Estimates of cooling overhead may vary across campus; a range of 75% to 125% is realistic.
value to this. However, the committee did note that some locations used to house computers are prime campus space that could be used differently if researchers were encouraged to adopt MGHPCC.

(3) The CRC recognizes the need to find a financially sustainable model from both researcher and Institute administration perspectives. The costs for a shared system could include recovery of any or all of the following: MGHPCC construction costs, MGHPCC invoice amounts, costs for computer hardware and costs for personnel to support an adequate level of service. In arriving at the recommendation for a shared system pilot program, we made a brief analysis of a hypothetical cost recovery model that might be used to sustain such a shared system. This analysis is approximate and intended for planning purposes only. It does suggest that sustainable charges would be significantly less than commercial cloud provider rates, and that the level of service could be higher. We chose to base our analysis on the following assumptions:
a. Building construction costs, energy costs, building operations and maintenance costs and campus network access costs are not included in the usage charge. This is consistent with general practice that these costs are met from other sources at MIT.
b. The cost of computer equipment for a single rack is assumed to be around $200,000, and the equipment is assumed to have a useful lifetime of four years.
c. A single rack of computer equipment is assumed to hold the equivalent of 530 high-end CPU cores with at least 4GB of fast memory available per CPU core.
d. The personnel costs for providing a basic but acceptable level of service amounts to the dollar equivalent of a minimum of 2.5 FTE skilled staff. This is intended to be a planning estimate. It assumes a fairly high level of staff early on, on the premise that rapidly establishing a reputation for reliability and prompt response will be an important factor for any broad-based acceptance of the MGHPCC. Over time this level could well fall, as processes become more automated, opportunities for sharing costs with partner institutions appear, and as the ratio of computing to staff increases.
e. Personnel costs are amortized over at least 10 racks of equipment.

Using these assumptions we can estimate a nominal charge for a CPU-hour of computing and compare this with an equivalent commercial cloud computing rate.

<table>
<thead>
<tr>
<th>Number of racks</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Computer equipment cost/month</td>
<td>$42,000</td>
</tr>
<tr>
<td>MGHPCC charges included/month</td>
<td>$5,000</td>
</tr>
<tr>
<td>Staff compensation/month</td>
<td>$30,000</td>
</tr>
<tr>
<td>CPU hours available per month</td>
<td>3,800,000</td>
</tr>
<tr>
<td>User Charge ($/CPU hour)</td>
<td>0.021</td>
</tr>
<tr>
<td>Equivalent commercial rate ($/CPU hour)</td>
<td>0.15</td>
</tr>
</tbody>
</table>

Comparison with a commercial rate is complicated by the fact that commercial providers usually include a variety of plans, and rates that include sub-dividing CPU cores using virtualization techniques. There is emerging open source software that would allow an MIT shared system to do the same. Here we have made a single comparison between one high-end CPU core with 4GB of memory as charged by Amazon. This is a fair
comparison, although it is only one of many comparisons that could be made. In reality a shared system would likely offer more than one “plan” too.

Additional considerations to note are
a. The charges in the shared system model include basic, high-performance computing oriented support resources that are not included in commercial cloud provider models.
b. The hardware pricing estimates assume technology well suited to high-performance computing at scale.
c. Staffing costs realistically start at around 2.5 FTE for a reasonable service, but they do not increase at the same rate with additional equipment growth. For example adding a further 10 racks might be expected to increase the FTE requirement by as little as 0.5. This equates to a marginal cost for those added racks of $0.015/CPU/hour.
d. Charge estimates assume relatively high utilization. The actual level of utilization is hard to determine without a pilot study.
e. Charges assume that all costs are incurred against CPU hours. In reality and on commercial cloud providers, there are other charges. In particular, persistent storage is usually charged separately, as is network utilization above some threshold. The hardware estimates assume a system with some useful storage and network capability with the 10 racks. Charging for some of these would reduce the effective CPU charge required to recover costs.
f. Clock rates on high-end computers have plateaued in the last five years due to physical constraints. As a result, high-end computer systems have useful lifetimes that can extend beyond four years.
g. Other institutions in the MGHPCC have begun to give some thought to these issues. Over time it may be possible to develop common approaches among the MGHPCC institutions that can further boost service quality within a sustainable budget approach.
h. There is an overlap between the shared system approach described here and the so-called buy-in approach. This overlap would involve buy-in system contributors agreeing to the inclusion of their hardware in a pay-as-you-go pool when their systems are underutilized. An attraction for buy-in providers could be that funds would be returned to them for the portion of the equipment cost that was used. It is somewhat unclear whether there are grant restriction issues around this, but it is a model that some investigators have enquired about.
Appendix D: User Support at the MIT-Bates HPRCF

The infrastructure at the MIT-Bates High Performance Research Computing Facility (which is composed of 71 water-cooled racks, 10 kW of cooling power each) is supported by 0.7 FTE, paid for through the rack service charge. The users manage their own computers, including physical installation, system and applications software, system shutdowns and repairs. Several of the infrastructure systems (water flow, chiller operation, or UPS) are connected to a watchman’s alarm panel that alerts the Bates receptionist (during normal working hours) or the security guard (off-hours) to a problem. The receptionist or guard then calls appropriate personnel to deal with the problem.

The 0.7 FTE consists of 0.5 FTE technician, 0.1 FTE supervisor/engineer and 0.1 FTE system administrator. There are actually seven technicians at Bates with varying areas of specialty who contribute to this 0.5 FTE; they are primarily supported by a number of other projects taking place at Bates. This number of technicians also allows Bates to have redundancy and 24/7 availability. Also, the engineering and technician infrastructure has allowed Bates to repair equipment issues that would have been very costly to repair otherwise.

The technicians maintain and repair the chilled water system, the rack back-door cooling systems and the electrical systems including the UPS’s for one rack row and the main network switch. The rack service charge also pays for service contracts on the chiller and the UPS’s, with the technicians and supervisor serving as a point of contact for the repair person. The technicians are also available for user assistance with physical installation, as time allows. In the event of a power failure or an alarm for one of the infrastructure systems, technicians respond 24/7.

The supervisor and engineer also monitor the health of the HPRCF systems, from water flows to temperatures, humidities and network health. Other projects at Bates provide the majority of support for the supervisor and engineer. The system administrator is available for a minimal level of hardware support, including shutting down or restarting computers, swapping out failed disk drives, etc. This saves HPRCF users from traveling the 25 miles from campus to Bates when all that is needed is a simple power cycle of one computer, for example. The system administrator spends most of his time supporting one of the large users of the HPRCF; this user group covers most of his support.

MIT Department of Facilities personnel also perform some services for the HPRCF, as DoF is responsible for the air conditioning in the mechanical services room, the network room, and the HPRCF area.