REPORT TO THE PRESIDENT

Developing Open Source Software to Advance High End Computing

President's Information Technology Advisory Committee

Panel on Open Source Software for High End Computing

October 2000

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Developing Open Source Software To Advance High End Computing

PRESIDENT'S INFORMATION TECHNOLOGY ADVISORY COMMITTEE

Panel on Open Source Software for High End Computing

October 2000

President's Information Technology Advisory Committee

September 11, 2000

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The Honorable William J. Clinton
President of the United States
The White House
Washington, DC 20500

Dear Mr. President:

The President's Information Technology Advisory Committee (PITAC) is very pleased to submit the second report in the series of follow-ups to our February 1999 report to the President, *Information Technology Research: Investing in Our Future*. *Open Source Software for High End Computing* highlights our recommendations for a research strategy that uses open source software development as the new model for answering America's high end computing software needs.

In our February 1999 report, we noted with concern a growing national vulnerability based on the inadequacies of the current system to build reliable and secure software while the diversity and sophistication of the software base becomes increasingly pervasive in society. The PITAC believes the open source development model represents a viable strategy for producing high quality software through a mixture of public, private, and academic partnerships. This open source approach permits new software to be openly shared, possibly under certain conditions determined by a licensing agreement, and allows users to modify, study, or augment the software's functionality, and then redistribute the modified software under similar licensing restrictions. By its very nature, this approach offers government the additional promise of leveraging its software research investments with expertise in academia and the private sector.

In the attached report, we focus exclusively on software development for high end computing (sometimes referred to as high-performance computing or supercomputing) because of its critical importance to U. S. national security and science and engineering research. Our 1999 analysis revealed that while there were a number of high end applications ripe for exploration, the field was in need of substantial innovations in application-development software, algorithms, programming methods, component technologies, and architecture.

The report makes three recommendations. First, the Federal government should aggressively encourage the development of open source software for high end computing. Adopting this recommendation will require a technical assessment of the software needs for high end computing as well as an innovative management plan and funding model for supporting this development. Second, a "level playing field" must be created within the government procurement process to facilitate open source development. Third, an analysis of open source licensing agreements is needed, with an ultimate goal of agreeing upon a single common licensing agreement for open source software applications.

Exploring alternative software development models for high end applications will allow the Nation to make significant progress towards addressing the growing national need to ensure software development practices and techniques which will result in reliable and secure systems. We are encouraged to see some high end computing and reliable software development research topics among the priorities your proposed FY2001 budget for Information Technology Research and Development. However, we urge you to implement the strategy outlined in our report in order to strengthen the effectiveness of federal investments and policies in this arena.

Thank you for the continued opportunity to advise you on these and other important issues for America's information technology-driven economy.

Sincerely,

Raj Reddy, Ph.D.
PITAC, Co-Chair

Irving Wladawsky-Berger, Ph.D.
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About This Report

"Developing Open Source Software To Advance High End Computing" is one in a series of reports to the President and Congress developed by the President's Information Technology Advisory Committee (PITAC) on key contemporary issues in information technology. These focused reports examine specific aspects of the near- and long-term research and development and policies we need to capture the potential of information technology to help grow our economy and address important problems facing the nation.

The 24-member PITAC, comprising corporate and academic leaders, was established by Executive Order of the President in 1997 and renewed for a two-year term in 1999. Its charge is to provide the Federal government with expert independent guidance on maintaining America's preeminence in high performance computing and communications, information technology, and Next Generation Internet R&D.

In February 1999, the PITAC issued an overview and analysis of the current state of Federal information technology research and development in a report entitled "Information Technology Research: Investing in Our Future." That report set forth a vision of how information technology can transform the way we live, learn, work, and play, with resulting benefits for all Americans. But the report warned that Federal information technology research and development is seriously inadequate, given its economic, strategic, and societal importance. The Committee concluded that the government is funding only a fraction of the research needed to maintain U.S. preeminence in information technology and propel the positive transformations it enables.

The Committee identified 10 information technology "National Challenge Transformations" that are critical to America's future. To meet these transformation challenges, the PITAC recommended a strategic Federal initiative in long-term information technology R&D and outlined the research priorities that will drive the necessary advances in the new century.

The PITAC subsequently convened a group of panels led by Committee members and including invited outside participants with relevant expertise to examine some of the transforming applications of information technology in greater detail. Three panels focused on information technology national challenges: Transforming Government, Transforming Health Care, and Transforming Learning.

Several other panels examined critical technology issues that span the transformations, including Digital Divide Issues, Digital Libraries, International Issues, and Open Source Software for High End Computing. Over the past year, each of the panels has analyzed relevant research data and documents; held workshop discussions and conducted interviews with experts in their fields; and studied the fiscal, organizational, and economic implications of strategies to generate necessary information technology research and development advances in these key areas of our national life. The Committee plans to convene additional panels in the months ahead.

"Developing Open Source Software To Advance High End Computing" and the other reports in this series present targeted findings and recommendations to the President and Congress designed to help the nation realize the vision of these positive transformations. Their benefits for our future can be extraordinary, but they are not guaranteed. To make the vision a reality, we need the results of aggressive, well-funded, and well-managed Federal research programs.

Acknowledgements

The Panel on Open Source Software for High End Computing wishes to acknowledge with gratitude the special contributions of the individuals and organizations that assisted us in the preparation of this report. We owe thanks to Thomas A. Kalil, Special Assistant to the President for Economic Policy, for encouraging the PITAC to undertake this study and supporting our efforts, and to the Federal agency members of the technical working group on open source software who generously shared information and discussed the issues with us. We wish to thank the staff of the San Diego Supercomputer Center for hosting and providing teleconferencing capabilities for our two-day open source software workshop. We are grateful to Rick Stevens of Argonne National Laboratory and John Toole and the staff of the National Computational Science Alliance, who helped organize the workshop and provided a remote host site and audio and video hook-ups to the workshop at the Alliance's ACCESS DC center.

Our special thanks to Jerry Sheehan of the National Center for Supercomputing Applications, who not only staffed the Panel but played a lead role in drafting our report. We thank his colleague, Lex Lane, for his able staff and logistical support.

The Panel would also like to acknowledge the work of the National Coordination Office for Computing, Information, and Communications in supporting its efforts to produce this report. The Panel thanks Krish Namboodiri, who coordinated Panel activities and kept us on track toward our final report. We thank Yolanda Comedy, Sally Howe, Laurie Mitchell, and Kay Howell for supporting the Panel's deliberations, for their review of earlier drafts of this report, and for their helpful comments. We thank Martha Matzke, who edited and formatted the final document. And we are grateful to the entire staff at the National Coordination Office. Our meetings went smoothly because of their careful preparation.

The Need for Fundamental Research In Software for High End Computing

In high end computing as in other areas of information technology, we need more fundamental research—the kind of groundbreaking, high-risk research that will provide the ideas and methods for new disciplinary paradigms a decade or more in the future. Our greatest needs are improving systems software and algorithm-level software support at the high end, exploring innovative architectures and devices, and making it possible for the academic research community and the Federal Government to conduct essential research and development on computers of the highest possible performance.

...

The Committee recommends substantial investment in software to improve the performance and efficiency of high end computers. The software investments fall into three categories: system software, algorithm development, and software to manage integrated systems in a balanced fashion. Investments in system software-languages, compilers, runtime libraries, operating systems, file systems, I/O drivers, debuggers, programming interfaces, performance tuning tools, and so on will lead to improved efficiency and performance and will make high end systems usable by a much larger community.

PITAC Report, February 1999

Overview

The President's Information Technology Advisory Committee (PITAC) charged the Panel on Open Source Software for High End Computing with developing a technology-research strategy and rationale for using open source software development as a new model for answering America's high end computing software needs.

The panel was charged with:

- Charting a vision of how the Federal government can support the developing open source software activities for high end computing
- Defining a policy framework for accomplishing these goals
- Identifying policy, legal, and administrative barriers to the widespread adoption of open source software efforts
- Identifying potential roles for public institutions in open source software economic models

The following report defines open source software, explains the PITAC's interest in this model, and describes the process the Panel used to investigate issues in open source software for high end computing. The report concludes with the Panel's findings and recommendations to the President and Congress.

What is open source software?

"Open source" is a generic term for software that is intended to be distributed to anyone who wants it, possibly under certain conditions determined by a licensing agreement. With the explosive growth of the Linux open source operating system over the last several years, the term has become increasingly commonplace.

Two critical characteristics of open source software are:

- Access to source code: Source code is distributed along with executable binaries. This access allows users to modify, study, or augment the software's functionality.
- Any licensing agreement must allow distribution of the initial software and redistribution of that software in modified form. Common examples of open source licensing agreements include the General Public License (GPL) developed by Gnu's Not Unix (GNU) and the Berkeley Software Distribution (BSD). (A list of some of the most common open source licenses can be found at

http://www.opensource.org/licenses/.) There are significant differences among licensing approaches. For example, certain licenses require all later modifications to remain open, while under others the initial open source code can be included in later proprietary releases. The choice of which license to use may be motivated by a number of factors, including the desire of distributors to limit their liability stemming from use of the software.

Open source software can arise from a number of software development processes. Eric Raymond defines two approaches to software development in "The Cathedral and the Bazaar." In "cathedral" style development, the dominant method in developing software under the proprietary model, projects are centrally managed, with strict project deadlines and defined staff, and beta testing is limited. In the "bazaar" model, dominant in the open source community, there is a radical decentralization of authorship, project managers rise on the basis of their programming talent, projects have distributed team members who come and go, and communitywide testing and debugging of releases is ongoing. Both development processes have benefits, contingent upon the specific need at hand.

Finally, open source software development is not "new." A number of successful open source software development efforts predate the "dot-com" revolution. Examples include the BSDUnix operating system, the BIND software implementation of Domain Name System (DNS), GNU programming tools, TeX software for document formatting, the Emacs editor, the gcc compiler, and Sendmail, a Simple Mail Transfer Protocol (SMTP) for e-mail.

What has fueled the recent interest in open source efforts is the pervasiveness of the Internet and the World Wide Web. Put simply, the emerging global information infrastructure enables programmers worldwide to work more easily in a distributed fashion to develop software. This condition creates a dynamic synergy allowing virtual teams who have never met face-to-face to form communities based on self-interest to improve existing software products.

Why is PITAC interested in open source software?

In a primary recommendation of its February 1999 report to the President, the PITAC called on the Federal government to make fundamental software research an absolute priority for Federal investments. PITAC members noted with concern a growing national vulnerability resulting from the inadequacies of the current system in building reliable and secure software, even as the diversity and sophistication of the software base becomes increasingly pervasive in our society. The PITAC concluded that the open source software model merited investigation because it offered a unique approach to producing robust software through a mixture of public, private, and academic partnerships. By involving these multiple communities, open source development efforts offered the additional promise of allowing the government to leverage Federal funds with existing human infrastructure in the academic and business sectors.

The PITAC Panel on Open Source Software chose to focus on high end computing for a number of reasons. First, the Committee recognized that high end computing (HEC) was an enabling technology for U.S. national security and was essential to science and engineering research. Second, the 1999 PITAC analysis of high end computing noted that suppliers of high end systems were becoming an ever-smaller fraction of America's information technology-driven economy. Indeed, the absolute size of the high performance computing (HPC) market seems stable to declining. The Committee's technical analysis revealed that while there were a number of high end applications ripe for exploration, the field was in need of substantial innovations in application-development software, algorithms, programming methods, component technologies, and architecture.

Members of the high end computing community have recognized these circumstances for a number of years, as market forces have pushed vendors away from finding profitability in developing, or maintaining, software tools for the high end. Open source software efforts focused on high end computing may offer a unique way to increase the "mind

share" of programmers focusing on HEC software needs. However, the high end community has a perennial labor shortage for HPC systems software developers, and just moving to open source will not solve this human resource shortage. Existing high end computing vendors have expressed interest in the open source model, which holds the promise of allowing them to partner with sophisticated technical users to develop tools in a public-private partnership while also bolstering America's scientific leadership.

Finally, open source software was of interest to the PITAC because of its potential economic and societal benefits. Many information technology analysts argue that this model could have profound economic and social impacts. The European Union Working Group on Libre Software, which has conducted a comprehensive analysis of this potential, noted in its December 1999 report, "In our opinion, if the open source community becomes strong in any area of the world, that area has a far greater possibility of competing in a software market with changing rules, and the society in that area can benefit earlier from reduced costs, greater economic activity, and widespread diffusion of new technologies." (Free Software/Open Source: Information Society Opportunities for Europe, December 1999, Version 1.0, p. 22)

Panel process

The Panel on Open Source Software for High End Computing was formed in October 1999. Larry Smarr was asked to chair the Panel and held a first meeting with his steering committee in November. Susan Graham later agreed to co-chair the Panel and made the group's final presentation to the PITAC. The steering committee, composed of representatives from universities; Federal agencies, national laboratories, and vendors, recommended an aggressive timeline for completing the research necessary to develop the Panel's recommendations. After a number of steering committee teleconferences, the group agreed that the best mechanism to bring together interested constituencies would be to convene a two-day workshop. The steering committee also recommended that the full Panel membership be intellectually diverse,

representing the breadth of communities interested in this topic. (Please see page viii for the list of Panel members.)

Investigation by the steering committee and full Panel brought to light an existing multiagency/academic/industry effort that focuses on understanding the technical needs of the high end computing user that could be met by open source software. (For more details, please see Appendix A, page 12.) This technical working group was driven by its members' recognition that open source software might help stem the looming crisis in software for high performance computing systems. The technical working group's goal is to develop technology roadmaps defining the various components necessary for high end computing users that could be developed using open source methods. The group has held five major meetings, most recently on February 17-18, 2000. A number of PITAC Open Source Panel members participated, briefing the technical working group on the Panel's efforts and discussing the proposed technical roadmaps.

Working with the National Coordination Office for Computing, Information, and Communications, the San Diego Supercomputer Center (SDSC), and the National Center for Supercomputing Applications (NCSA), the Panel hosted a two-day workshop on March 23-24, 2000. Participation was either in person at a site hosted by SDSC, or via video-teleconference from an NCSA site outside of Washington, D.C. The workshop was by invitation, with speakers selected by the steering committee to cover specific technical topics and represent the views of various communities. (Please see Appendix B for the list of speakers and participants.)

The information and perspectives gathered in the Panel's interaction with the multiagency technical working group and the two-day open source software workshop served as the basis for the following findings and recommendations.

Findings

[/* Open source software development efforts are a promising means to enable high end computing and should be considered an important infrastructure investment by the Federal government. The Federal government should share in the open source development activity and be prepared to fund the development of appropriate new tools and to support, distribute, and provide maintenance for that software. Currently, developers within government agencies and government-funded research groups have virtually no funds available for these efforts.

[/* "Bazaar-developed" open source software is inherently community-driven and as such represents a grass-roots approach to answering user needs. A critical aspect of this approach is leadership based on merit without regard to external administrative hierarchy. A nontraditional model of funding and project management needs to be developed for the use of open source software in the Federal government, if the power of the voluntary association approach of the open source movement is to be tapped.

[/* Open source software development, in the age of the Internet, is an international activity. It would be unrealistic for government policy to be developed in a U.S.-centric fashion. Indeed, the very nature of this international collaboration raises substantial policy questions in export control.

[/* Open source software may offer potential security advantages over the traditional proprietary development model. Specifically, access by developers to source code allows for a thorough examination that decreases the potential for embedded trap doors and/or Trojan horses. In addition, the open source model increases the number of programmers searching for software bugs and subsequently developing fixes, thus reducing potential areas for exploitation by malicious programmers.

[/* Numerous licensing agreements are being used by the open source community. Development efforts may encounter incompatible licensing requirements leading to delays in project development and software distribution. More education is needed within Federal agencies to enable managers to understand the nuances of existing open source licenses and the conditions under which each licensing agreement should be used.

[/* Existing Federal procurement rules do not explicitly authorize competition between open source alternatives and proprietary software. This ambiguity often leads to a de facto prohibition of open source alternatives within agencies. There seems to be a general lack of guidance about what circumstances make an open source or proprietary approach appropriate. Panelists agreed that in certain circumstances proprietary approaches add the most value, while in other circumstances open source software, together with appropriate licensing arrangements, may have benefits. The emerging "mixed marketplace" containing both proprietary and open software may lead to some subtle but important policy issues. For instance, if there is a well-defined interface to vendor-provided system service software, should an open source alternative be developed? What is the process for insuring that proprietary code is not incorporated into open source distributions? Should the technical scope of the open source effort be limited to allow the necessary software to be created but not unduly disadvantage the private sector?

[/* Open source projects are often difficult to initiate within the Federal government due to a lack of understanding about whether the principal investigator, the principal investigator's institution, or the funding agency has authority and/or responsibility for deciding whether or not a project should be an open source one.

[/* The European Working Group on Libre Software identified the lack of data warehouses for open source projects as an obstacle to development efforts. The PITAC Panel notes with concern that this is also an obstacle in high end computing, where there is currently no inventory of high end computing open source efforts.

[/* The success of Linux was based in part on the easy availability of hardware development platforms. Access to HEC hardware is essential for experimentation and debugging of open source software for high end computing.

[/* Open source software may impact three classes of high end computing systems:

- Conventional massively parallel processors (MPPs) provided by mainstream vendors
- Rapidly emerging clusters that are significantly improving price-performance for some classes of problems
- New research on prototype architectures

[/* A robust multiagency effort is under way to develop technical specifications for open source software needs within high end computing. The Panel applauds these efforts and endorses multiagency approaches and workshops to help encourage consensus.

[/* Large opportunities may exist outside high end computing for open source software development efforts, in particular within embedded systems. The Panel did not examine these possibilities in depth because they were outside its charter and the Panel lacked the expertise necessary for an in-depth analysis.

Recommendations

Recommendation 1. The Federal government should encourage the development of open source software as an alternate path for software development for high end computing. Such a Federal initiative should address:

<a.> A technical assessment of the software needs in high end computing and the development of a technical plan for producing that

software. If possible, such an effort should build on the multiagency effort that is already under way. In true open source style, the technical planning process needs to be open and an effort needs to be made to ensure widespread opportunity for comment and contributions to the plan.

<b.> A management plan, funding model, and cost estimate for supporting a robust open source development effort in high end computing Such a plan should address:

- The community-driven, "merit-based" approach to software development
- Models for "fiscal flexibility" that recognize the unique characteristics of open source development
- The system integration process
- The relationship between open source software and private-sector proprietary software
- Identification of participating agencies

<c.> The policy implications of current export control regulations and national security concerns related to the development of open source software for high end computing. This analysis should address in specific terms the question of whether there are advantages for the U.S. in undertaking an open source development model for HEC, given the model's increasing popularity in the international community.

<d.> A plan for the creation of a Web clearinghouse, akin to http://www.collab.net/, where Federal agencies could post high end computing software needs and direct fiscal and programming resources to work with the open source software community to develop required applications.

<e.> A process developed through coordination between Federal agencies and leading high end computing hardware vendors to provide access to needed HEC hardware for developer testing. Such access is deemed essential if the open source community is to develop software for high end systems. These efforts should also focus on moving critical

pieces of open source software into "tool kits" for new system architectures.

Because of the underlying national security implications and scientific importance of high end computing and the critical need for HEC software, we recommend that this plan be developed before the start of the next Federal fiscal year.

Recommendation 2. The Federal government should allow open source development efforts to compete on a "level playing field" with proprietary solutions in government procurement of high end computing software. Requests for Proposals (RFPs) from Federal agencies for high end computing software, tools, and libraries should include provisions allowing these efforts to be carried out using open source.

Recommendation 3. An analysis of existing open source licensing agreements should be undertaken, and the results should be distributed to all agencies funding high end computing. The analysis should describe characteristics of each license and give specific examples of situations in which it may be preferable to use one type over another. The use of common licensing agreements should be encouraged.

Appendix A

Technical working group on open source software

In August 1999, a multiagency Federal group was formed to define the technical requirements for developing open source, community-owned and -maintained software for high end computing systems. This technical working group, composed of representatives from the Department of Energy (DOE), the National Aeronautics and Space Administration (NASA), the National Security Agency (NSA), and the National Science Foundation (NSF), held a number of community meetings to raise awareness of the potential of this approach and to begin to define what they see as the future direction of high performance computing.

Early in Spring 2000, the technical working group focused its efforts on defining technology roadmaps for needed system components. This thorough effort has included extensive guidance from computer scientists as to the tools that need to be developed and a realistic timetable for constructing the building blocks of an open source software system for high performance computing.

The working group plans to have a draft version of the technical roadmaps available online for community comment in the near future.

Appendix B

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President's Information Technology Advisory Committee