Foreword

Arthur C. Clarke wrote in *Profiles of the Future* that "any sufficiently advanced technology is indistinguishable from magic" (Clarke, 1961). Nowhere is Clarke's "third law" more in evidence than in the case of information technologies that have been brought to bear on the process of research. Information technologists enjoy their roles as agents of change, and the language and rhetoric of transformation and revolution have long dominated our community. Indeed, high-performance computation, networking, mass storage, scientific visualization, modeling, manipulation of large data sets, and other elements of research computing have transformed science. It is indisputable that information technology (IT) has not only enabled a breathtaking increase since the 1940s in global research output and productivity, but it has also enabled research breakthroughs that simply could not otherwise occur.

Thanks to IT, fundamentally new research domains have opened: genomics and phonemics, computational chemistry, atmospheric informatics, remote sensing and photogrammetry, and many others. IT has exploded the boundaries between traditional academic disciplines and magically expanded the human capacity to hear, see, visualize, and simulate phenomena. Atmospheric nuclear tests are now anachronisms, replaced by computer-generated models and simulations. Pharmaceuticals are designed online. Econometricians use computerized models of economies to test the impact of new taxes, natural disasters, and changes in monetary policy, while engineers use IT to simulate earthquakes or to model the impact of accidents on traffic flows. The engagement of IT in research has quite simply been magical.

This engagement has held this promise from the beginning. The 1947 patent application (No. 3,120,606) for ENIAC stated, "With the advent of everyday use of elaborate calculations, speed has become paramount to such a high degree that there is no machine on the market today capable of satisfying the full demand of modern computational methods. The most advanced machines have greatly reduced the time required for arriving at solutions to problems which might have required months or days by older procedures. This advance, however, is not adequate for many problems encountered in modern scientific work and the present invention is intended to reduce to seconds such lengthy computations."

And so a new dance began. It is essential to recall that in this beginning, science, research, and computing were simply not separated. Computer science, as a discipline, was born among the mathematicians, physicists, and others like Alan Turing and John von Neumann. It was the birth of "big iron." "By today's standards for electronic computers the ENIAC was a grotesque monster. Its thirty separate units, plus power supply and forced-air cooling, weighed over thirty tons. Its 19,000 vacuum tubes, 1,500 relays, and hundreds of thousands of resistors, capacitors, and inductors consumed almost 200 kilowatts of electrical power" (Weick, 1961).

The story of IT's engagement in research is unique among ECAR research stories. First, unlike many stories that suggest heroic efforts and equivocal results (*Identity Management in Higher Education: A Baseline Study*, Yanosky, 2006), or even ambivalent efforts and disappointing results (*Good Enough! IT Investment and Business Process Performance in Higher Education*, Kvavik & Goldstein, 2005), the story of IT's engagement in research is an unambiguous success. No scientific discipline has remained unchanged in the wake of technology's intrusion, and few researchers in nonscientific disciplines doubt the transformative impacts that IT will have on these disciplines. Indeed the American Council of Learned Societies in November 2005 described the grand challenge of the humanities and social sciences as an IT challenge: "We have the opportunity to reintegrate the cultural record, connecting its disparate parts and making the resulting whole available to one and all, over the network" (ACLS, 2005). A magical vision. The story of IT's engagement in research is unique, too, insofar as it is a story in which the CIO and the central IT organization have, so far, played chiefly a supporting role. That role has been most often confined to the provision of fast networks and connections to regional networks, gigaPOPs, the NSFNET, vBNS, Abilene, and others. Much of the work in scientific computing takes place in the laboratories under federal and other contracts and grants.

This story can be told in sweeping and dramatic chapters. "Monsters" like ENIAC built in the 1940s and 1950s were large, expensive beasts demanding considerable institutional attention, care, and feeding. As IT was commercialized, its costs, while large, went down along with the scale. By 1965, machines like DEC's PDP-8 were small enough for dedicated use in specific laboratories, and minicomputers proliferated around university research facilities. These were tended typically by graduate students—usually physicists, mathematicians, engineers, and others. In the mid-1960s, digital computing laboratories began to reorganize as computer science departments, and the first holders of advanced computer science degrees graduated in the late 1960s and continue to hold leadership positions at our major research universities today.

The professionalization of the computer science workforce, along with the changing nature and scale of computation, resulted in a bifurcation of responsibilities for IT in research. Many computational experts remained "of the discipline" and sought employment within research labs, albeit in computational specialties. Others became directors of university computer centers, latter-day CIOs. Differing roles, pressures, and accountabilities increased the sense of professional differences among these members of the IT tribe, differences exacerbated by the peculiarities of funding from research sponsors. Federal funding in particular placed the management of scientific and research computing outside the influence of the central campus, and in many cases innovation flowed from the research center to the campus center in an uneasy balance of technical sway.

IT's engagement in research changed again in the late 1960s with the deployment of the ARPANET and the eventual stitching together of campus and regional networks to the national NSFNET backbone. The hand of the central campus IT providers was strengthened as the importance of networking in research rose.

From the late 1960s until now, an uneasy coexistence among campus computational cousins has persisted. Central campus IT leaders provide the network bandwidth needed by those on campus doing computationally intensive research. User support, visualization, maintenance of computing clusters, and management of scientific databases and data sets is often vested in the research departments and programs.

Taking the Next Step

The nature and scale of computing are changing again, and this study is written amidst a view that perhaps the story of IT's engagement in research is about to turn another chapter. Indeed, at several leading institutions (as profiled in the case studies accompanying this research study) new partnerships between central and local campus IT providers are already under way. In January 2003, the Blue Ribbon Panel on Cyberinfrastructure of the National Science Foundation issued a report concluding that "digital computation, data, information, and networks are now being used to replace and extend traditional efforts in scientific and engineering research, indeed to create new disciplines" (NSF, 2003). The report goes on to detail a vision of a cyberinfrastructure that would make a vast and rich array of research resources available globally to researchers anywhere and anytime.

The challenges of the cyberinfrastructure are at least as daunting—and costly—as was the challenge of integrating the 1970s hodgepodge of nonstandard local networks into what has become the global Internet. The achievement of this vision, particularly in an era of relative economic scarcity, suggests to me the need to rethink fundamentally that uneasy truce—not quite governance—between CIOs and their cousins in the laboratories. The cyberinfrastructure vision demands a degree of collaborative management, a layer of centrally managed authentication and authorization middleware, and a level of security that all beg moving the fulcrum between central and local management of resources closer to the institutional center in many areas. Similarly, the robustness and ubiquity of networks also suggests that large-scale computing is more than ever a game of scale economics as the cost of physical space and electrical power begin to dominate the life-cycle costs of research computation.

Then, too, there is the issue of the "cultural record." Under today's fragmented responsibilities, too many irreplaceable research data sets are being lost due to neglect that too often occurs when research funding dries up. Finally, the cyberinfrastructure vision is in the end one of research collaboration—and collaboration is an artifact of environment, culture, language, and other things that benefit from simplification, standards, and scale. This is not likely to be a case where "the nice thing about collaboration environments is that there are so many to choose from."

This potential inflection point, then, is the backdrop for this study. Under Harvey Blustain's leadership, ECAR has asked a number of questions:

- What major issues are CIOs confronting in the research arena?
  - Demand for more bandwidth? More cycles? More storage?
  - Funding and resources?
  - The ability to provide support to faculty?
  - Difficulty in managing diverse research environments?
- What does the shift in thinking toward "cyberinfrastructure" mean for CIOs in terms of strategy, investments, support demands, and partnerships?
- What impact are changes in the funding environment having on their institution's research agenda? On their organization's ability to provide support for research?

- How is the role of the central IT organization changing with regard to research? What changes are they observing in the local IT organizations to accommodate researcher needs?
- What are they seeing or what role are they playing in the shift toward greater interdisciplinary research?
- What interinstitutional consortia do they participate in, and how has that affected researcher access to infrastructure? What changes have partnerships precipitated in internal IT operations? What impact will they have on the future of their IT organization and services?
- Has the institution formed partnerships with private-sector entities? What has been the impact on the demand for services and support?
- Looking to the future:
  - What will be the more important drivers of change for research-related IT over the next 15 years?
  - What will the IT units (central and local) within higher education look like in 15 years?
  - How will such issues as data privacy and public access to federally funded research affect computing in higher education over the next 15 years?
  - What role will the federal government, through funding criteria, play in establishing IT infrastructure over the next 15 years? Will mandates from state legislatures have an impact?

These questions framed our research. This story is extraordinarily complex, and this research can only be characterized honestly as preliminary. IT's engagement in research is pervasive and includes the obvious, such as high-performance computing and networking, mass storage, visualization, and so forth, and the more nebulous areas such as e-collaboration, management of research data sets, research metadata, and on and on. Limitations of time and money and the urge to move quickly caused us to limit the scope of this research endeavor to what some will consider the obvious. That was my choice; if you, the reader, are unsatisfied, bring your complaints to me.

With that said, ECAR has invested significantly and enthusiastically in this topic. Along with this baseline study, ECAR is proud to publish Sandra Braman's provocative essay *What Do Researchers Need? Higher Education IT from the Researcher's Perspective.* ECAR readers will also enjoy an unprecedented five case studies in this arena, including studies undertaken at Georgetown University; Princeton University; Purdue University; University of California, Irvine, and University of California, San Diego; and the University of Virginia. We are indebted and grateful to our colleagues at these institutions for opening their doors and their calendars to us.

Boundaries Are Diminishing

One last bit of magic. While we are deeply grateful to our colleagues at 328 U.S. and Canadian colleges and universities who responded to the survey that underpins this analysis, I regret the many notes I received from those colleagues who declined to participate. Most indicated that "research is not a high priority at this institution." It seems to me that one aspect of the inflection point we are reaching is that of IT rendering all sorts of "digital divides" meaningless. It is already clear that divides separating academic disciplines are being challenged and moved aside in the wake of the IT torrent. It has long been clear that networks have rendered geographic divides meaningless, and teams in modern genomics, particle physics, deep space astronomy, geophysics, atmospherics, and other big-science disciplines are inherently multi-institutional and multinational. The reticence of some of our colleagues to participate in this research reveals perhaps a stubborn divide: that related to institutional mission. If the premise of the research university that great research and great teaching are mutually reinforcing is true, then the boundary-challenging vision of cyberinfrastructure is creating the potential to blur the hard boundaries of institutional mission. Indeed it is now possible to find people like Maria Crawford, a world-famous MacArthur Prize–winning geoscientist who conducts data-intensive research from Bryn Mawr College, her alma mater. As these borders continue to erode, the answer to the question "where do you do your research?" will be "in cyberspace."

As always, the report that follows comprises the hard work of many people at ECAR. Harvey Blustain led a team that included Sandra Braman, Bruce Metz, Judy Pirani, Gail Salaway, Don Spicer, and me on this core baseline report. Harvey is an accomplished consultant and anthropologist who tells here a compelling and interesting story. This story was framed on the basis of the good advice we received from our advisors. ECAR extends thanks to William F. Decker, senior associate vice president for research, University of Iowa; Clifford Lynch, executive director, Coalition for Networked Information; Michael McRobbie, vice president of academic affairs and provost, Indiana University; Bonnie Neas, associate vice president, federal government relations and director, Center for High Performance Computing, North Dakota State University; Linda O'Brien, vice principal (information), University of Melbourne; Bruce Pipes, vice president of academic affairs, Franklin & Marshall College; George Strawn, CIO, NSF; and Ellen Waite-Franzen, CIO, Brown University. As always, this research is made immeasurably better by the EDUCAUSE team that is responsible for rendering it into an attractive, readable, and usable form. Thanks especially to Greg Dobbin, Nancy Hays, and Toby Sitko of EDUCAUSE and our contractors Bob Carlson, Anne Lear, Julianne Snider, and Stephen Larghi. It is a pleasure and an honor to work among smart and talented people.

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