**CLIMATE CHANGE INSTITUTE STRATEGIC PLAN**

 **2019**

**Fifty years of research at the Climate Change Institute**

From its formal beginnings nearly 50 years ago, the Climate Change Institute (CCI) of the University of Maine has been a leading center of interdisciplinary research focused on how the Earth’s climate has changed from the peak of the most recent ice age to the present. UM scientists have led expeditions from pole to pole, spanning the abyssal ocean to the highest Himalayan peaks, painstakingly collecting an unparalleled body of field data that reveal the natural variability of the global climate, and ultimately the mechanisms that cause that variability. Researchers from UM have studied the changing conditions of ice sheets, oceans, the atmosphere, the biosphere, the hydrosphere, and human cultures, which have been co-evolving for thousands of years.

***It is only through a well-founded understanding of the natural variability of the Earth’s climate that we now can determine whether the changes occurring within our new, high-CO2 climate are moving beyond “normal” or natural fluctuations of Earth’s recent past. Moreover, our rapidly growing understanding of the mechanisms behind past climate variability allow us to make more accurate predictions of the future and provide much-needed context for climate-change mitigation and societal adaptation.***

Decades of careful, detailed fieldwork by CCI faculty, staff, graduate students, and undergraduate students has enabled a new perspective on global climate. As a result, we now stand on the edge of a revolution in our understanding of the Earth system. Ultimately our world-class field observational capacity can improve climate modeling and forecasting. Latest-generation coupled climate models, tested against paleoclimate data and developed to their most advanced state, can be used project future change. As a community, the members of CCI provide a long-term climate perspective and expertise that is uniquely un-bounded by traditional academic divisions and vital to future climate projections. We are poised to meet the challenges of a dynamic future climate.

As one of the first interdisciplinary climate research units in the world, and as a University of Maine signature program, CCI leads multi-, inter- and transdisciplinary research. CCI’s academic affiliations facilitate multi-disciplinary climate-change education at both the undergraduate and graduate levels. The Institute offers graduate students many opportunities to work in diverse fields and in diverse regions (poles to tropics and, of course, Maine). *Convergence Research*, now a major emphasis with NSF and similar agencies, has been the foundation of CCI for nearly five decades and a constantly evolving goal for climate research and education that is achieved through field, laboratory, technical and communication skills.

Climate change poses a significant threat to the future health and security of human societies and economies worldwide. Researchers from the Climate Change Institute are generating knowledge that is highly relevant to the development of public policies focused on climate mitigation and adaptation. For example, a major strength of CCI is research in the Arctic, where rapidly developing changes in the Arctic environment now have implications for Maine and the rest of the globe; focus on the changing Arctic is now one of NSF's major initiatives. CCI researchers are also working to understand contemporary systems for both greenhouse gas emissions mitigation and societal adaptation to a changing physical and chemical climate. Research in climate modeling, scaled to understand regional impacts, helps engineers and planners anticipate infrastructural adaptive needs. Research in communication-science, anthropology, economics, education, and international affairs reminds us that anthropogenic change is fundamentally a societal issue that necessitates the study of human perceptions, behavior, politics, and economic systems to yield insights for effective mitigation and adaptation policy formation.

The world-class research at CCI is important not only for global and national concerns, but also to our own state. Maine communities are adapting to sea-level rise, warming temperatures, the spread of climate-driven vector-borne disease, and an increase in extreme rainfall, all of which affect agriculture, tourism, recreation, and other sectors of the economy. Coastal communities are seeing flooding from higher storm surges, recurrent high tide nuisance flooding, increased coastal erosion, and more frequent ocean heat waves that may dramatically affect fisheries in the Gulf of Maine.

In short, CCI research helps us to understand the past in order to inform the present and anticipate the future. The Institute comprises more than 60 scientists of varied affiliations across multiple research themes (Appendix A). Its scholars have had remarkable success in supporting research by obtaining competitive federal funding through researcher-driven proposals. A high priority for CCI is to use its research accomplishments to strengthen policy-making in Maine and beyond. To that end, the following describes what we see as the Grand Challenges for the future and identifies ways in which CCI can build on our strengths to inform the challenges ahead.

 **MISSION STATEMENT**

The Climate Change Institute has a legacy of transformational contributions to human understanding of the physical, chemical, biological and social complexity of climate change and the application of these findings at local to international scales. Climate change is a major challenge for the 21st century, altering aspects of life on this planet that include human health, food supplies, biodiversity, and security issues for our country and the world. The Climate Change Institute, as part of its ever-evolving goal to understand and apply climate change findings, is addressing these issues through the following cross-disciplinary *“Grand Challenges”*.

1. ***Growing Convergence Research*** - Integrating knowledge, methods, and expertise from different disciplines and forming novel frameworks to catalyze scientific discovery and innovation.
2. ***Expanding Arctic Research and Education*** – Enhancing our world-renowned leadership as a center for research and education on Arctic change.
3. ***Climate Futures*** - Providing an interactive framework for developing plausible scenarios for near to long-term future climate with a focus on: health, ecosystem services, economy, hazards, environmental and energy policy, geopolitics, cultural heritage, and quality of life.
4. ***Improved Interactions with Decision-Makers*** - Unravelling human and environment interactions (past and present) as guidelines for better decisions now and in the future.
5. ***Big Data*** - Using interdisciplinary teams and innovative technologies to integrate diverse physical, chemical, biological, and social science data to solve climate-driven complex problems.
6. ***Enhanced Science Communication***– Bringing climate science into the public sphere with clear explanations and applications for people and ecosystems.

**I. GROWING CONVERGENCE RESEARCH**

***What does “Growing Convergence Research” mean?***

[NSF defines “convergence”](https://www.nsf.gov/od/oia/convergence/index.jsp) as “integrating knowledge, methods, and expertise from different disciplines and forming novel frameworks to catalyze scientific discovery and innovation,” and recently prioritized convergence research as one of its [Ten Big Ideas](https://www.nsf.gov/news/special_reports/big_ideas/index.jsp). CCI has a fifty-year history of “deep integration across disciplines” to address “significant and compelling problems” as a global leader in transdisciplinary, problem- driven research. From our roots in integrated physical, biological, and social sciences (glaciology, archaeology, climatology, paleoecology), CCI now does convergence deeply and with impact -- not only within STEM, but including art, policy, social science, and the humanities.

We identify several challenges going forward: 1) Maintaining deep, meaningful connections as we continue to grow (particularly facilitating interactions and maintaining a common language), 2) Proactively anticipating the challenges of climate change for human and natural systems (e.g., improved forecasting, communicating climate futures, strategic planning), 3) Enhancing data-model synthesis, 4) Improving forecasts, and 5) Training students in convergence research for dynamic workforce demands.

***What are the linkages with other Grand Challenges in this plan?***

Convergence research is the foundation for CCI’s efforts. Policy is informed by strong science, including modern and deep-time perspectives on local to global scales. The challenges of a changing Arctic require an integrated understanding of social, physical, and biological systems. Big Data provides tools to connect disparate, complementary models and data. Communicating convergent research requires working within and across disciplines, institutions, and the public sphere. The convergence framework provides tools for problem-driven, transdisciplinary approaches to these Challenges.

***What are the priorities for action over the next 5 years?***

* Continue open, out-of-the-box approaches to identify timely, relevant problems that convergence approaches can address within CCI.
* New or revised activities fostering interaction (workshops, meetings, field trips, partnerships, Borns Symposium, welcome event, seminar or speaker series on an annual theme or problem, INT 500, lab tours, statement papers).
* Using the A2C2 IGERT as a model, develop a new program for convergence collaborations, including seed funding for problem-based climate research.
* Hire a dedicated CCI communicator with a transdisciplinary background to conduct training and public outreach on convergent climate communication.
* Invest in infrastructure to support deep convergence research: dedicated technician(s), strategic reserve for equipment needs, travel funds to visit labs or conferences, gathering space (tea/lunch room) to foster interactions.
* Prioritize development activities to generate an endowment to fund the above.

**II. EXPANDING ARCTIC RESEARCH AND EDUCATION**

***What does “Expanding Arctic Research and Education” mean?***

NSF identifies “Navigating the New Arctic” as one of its [Big Ten Ideas](https://www.nsf.gov/news/special_reports/big_ideas/); other organizations such as NASA and the Department of Defense also recognize the Arctic as a critical current research, development, and security target. CCI and the University of Maine are well positioned to expand our role as an international leader in research on Arctic Change. The University of Maine is a “Gateway to the Arctic” institution, centrally located to provide easy access to Arctic regions that are experiencing significant change, including Greenland, Iceland, Canada, Alaska, Siberia, and the Arctic Ocean. CCI has an institutional legacy of knowledge and perspective from Arctic research expeditions over the past five decades. The State of Maine also has a clear need to understand challenges and opportunities associated with the Arctic. These include fisheries, forestry, and tourism, each of which are central to the Maine economy. The University of Maine also recently became the administrative home to the longest operating Polar Earth systems science field research and training program in North America, the Juneau Icefield Research Program (JIRP). JIRP has inspired generations of leading scientists, educators, and science advocates since 1946. Like CCI, JIRP has a tremendous legacy and is actively developing international collaborations to conduct a range of interdisciplinary Arctic and Sub-Arctic research that falls within existing CCI research themes. We plan to leverage this new partnership and resources available at JIRP to collaboratively expand our Arctic research and education presence. Expanding our already-established role as an international leader in Arctic research and education aligns closely with NSF, NASA, Department of Defense and NOAA Arctic goals. Leveraging our strengths within CCI to reach local, regional, national, and international communities, our goals within this grand challenge include:

● Improving our understanding of Arctic change and its local, regional, and global scale effects on the natural environment and on society (communities, infrastructure, and social systems);

● Enhancing interdisciplinary and collaborative research and education communities that are diverse, integrative, and well-positioned to carry out productive Arctic research, education, science communication, and sustainability initiatives;

● developing results that support U.S. national security and economic development needs and enable resilient, sustainable Arctic, U.S. and local (Maine) communities.

***What are the linkages with other Grand Challenges in this plan?***

Observed changing atmospheric patterns and conditions have significant impacts on permafrost, glaciers, ecosystems, and Arctic communities. Teleconnections between the Arctic and other regions of the world are also pronounced, albeit complex. Understanding these complexities requires an interdisciplinary or “convergence” approach and efficient analyses of big data to effectively improve our understanding of these systems. This integrated approach is also needed to make informed recommendations on policy and initiatives that will have positive societal, environmental, and economic impacts.

***What are the priorities for action over the next 5 years?***

* Integrate CCI Arctic initiatives into a working group, center, or other initiative to promote our key role in Arctic research and catalyze new collaborations & research questions.
* Strengthen connections and collaborations with UMaine Engineering, Physics, Science Communication, Social Sciences and Humanities programs to pursue more complex, convergence, and Interdisciplinary Arctic research initiatives.
* Explore philanthropic opportunities to provide baseline funding to our signature Arctic programs, new graduate and undergraduate training programs focused on Arctic, sub-Arctic, and mid-latitude connections.
* Promote awareness of how Arctic, sub-Arctic, and mid-latitude changes are linked to environmental, social, and economic realities in Maine.

**III. CLIMATE FUTURES**

***What does ‘Climate Futures’ mean?***

The interdisciplinary expertise of CCI is well suited for further enhancing its Climate Futures initiative, a program that facilitates future climate planning across local, regional, and global scales. Climate Futures invokes or will invoke climate and earth systems modeling, socio-economic research, data collection, environmental and biological monitoring, educational outreach, and plausible scenario planning. Climate Futures will expand the data access, analysis, and visualization capacity of CCI’s already publicly available and highly used (3000-4000 users per day) Climate Reanalyzer web framework. Climate Futures will also provide access to publicly available commodity data so that planners can examine climate-commodity connections.

***What are the linkages with other Grand Challenges in this plan?***

* Climate Futures does and will provide data, analysis, and interpretation, and plausible climate scenarios to help decision-makers in their adaptation and mitigation efforts, and therefore integrate closely with the Improved Decision-Making theme.
* Climate Futures does and will include education and stakeholder outreach that can utilize the communication conduits and support structures developed in the Enhanced Science Communication theme.
* Climate Futures will require an expansion of existing CCI data storage, analysis, and visualization frameworks (i.e., Climate Reanalyzer, 10Green, P301), and thus integrate closely with the Big Data theme.

***What are the priorities for action over the next 5 years?***

* Design and implement an integrative web framework to make climate, oceanographic, biological, commodity, and socio-economic data accessible to community, commercial, and governmental planners in order to enable the development of plausible future climate scenario planning.
* Collaborate with the UM Advanced Computing Group and School of Computing and Information Science to expand CCI’s data storage and cyberinfrastructure capability.
* Establish UMaine collaborations (e.g., SECS, SMS, SBE) to bridge gaps between 1) field-based and modeling researchers, and between 2) atmospheric and oceanographic researchers.
* Identify relevant environmental monitoring programs (e.g., local or micro climate, ecological, Gulf of Maine buoys).
* Increase communication and collaboration between CCI members and atmospheric and earth systems researchers through CCI’s affiliation with NCAR/UCAR.
* Pursue external support from both federal and private sources to further research in the areas of Arctic change, environmental monitoring, earth system modeling, socio-economic analysis (e.g., future climate impacts on cultural resources), and software infrastructure development, and others.

**IV. IMPROVED INTERACTIONS WITH DECISION-MAKERS**

***What does ‘Improved Decision-Making’ mean?***

CCI has a responsibility to ensure that the knowledge we generate reaches those who can most effectively act upon it. The challenges are: 1) to continue to produce world class research on past, present and future climate systems that can support decision-makers on multiple scales; 2) increase awareness and understanding of CCI research by developing relationships with and connections to policy-makers, legislators, business owners, and decision-makers on multiple scales to provide decision-support informed by current science; and 3) increase institutional capacity to provide knowledge-based, data-driven support to decision-makers.

***What are the linkages with other Grand Challenges in this plan?***

Much of what CCI does is relevant to decision-makers throughout our state and beyond, but even the best climate science fails to reach its full potential if it is not utilized. Work in this Grand Challenge fundamentally overlaps with all other elements of the strategic plan:

* Informing decision-makers requires effective and tailored communications skills to ensure users get the right information, when they need it, in clear and understandable language.
* Decision-makers need reliable information about plausible climate futures upon which to base both mitigation and adaptation decisions.
* Management of complex physical, biological, chemical, and social systems requires big data systems able to capture this complexity and avoid management of one point in the system that has emergent, unintended consequences at another.

***What are the priorities for action over the next 5 years?***

* Design and implement a sustainable, resource-efficient outreach program: leverage existing and emergent CCI data and tools (Climate Reanalyzer, 10Green, the Maine State Climate Office housed in CCI, and Climate Futures web frameworks) and implement strategies to get these resources to decision-makers through creative and efficient means (e.g., webinar series, CCI YouTube channel, local media, a newsletter, graduate student outreach/internships, external partners like Arctic Futures Institute, World Ocean Observatory [with >800,000 Facebook followers], and others). This should include enhanced capacity to connect users to appropriate experts (e.g. searchable expert database).
* Collaborate with existing University of Maine and University of Maine System campus institutions as well as other institutions for political and stakeholder engagement (e.g., University of Maine Law School, Business School, Margaret Chase Smith Policy Center, Cohen Institute, Advanced Structures and Composites Center, Forest Bioproducts Research Institute, Faculty Fellows program, Bodwell Center, Mitchell Center) to integrate climate-related programming into the University's existing and planned engagement efforts.
* Pursue external support for a graduate student national traineeship grant (e.g., NSF NRT), focused on climate planning and policy.
* Strengthen internal capacity (professional development, training) designed to help scientists work with and support policy and decision-makers on multiple scales (individuals, state legislators, town select people, national representatives, industry executives). This may include programming centered on learning to communicate research concisely, on decision-support platforms or on strategies for policy-engaged research.

**V. ENHANCED SCIENCE COMMUNICATION**

***What does ‘Enhanced Science Communication’ mean?***

CCI will pursue two broad and interrelated communications outcomes.

1. Communicate to multiple audiences within and outside of Maine the accepted science behind the topic of changing climate and its implications for society and inform audiences about the internationally recognized research conducted at the Institute. Target audiences include Maine residents, K-12 students, businesses, and local and state policymakers.
2. To communicate effectively with these audiences, CCI recognizes the need for research-based understanding of how such aspects as message characteristics, information processing, and other socio-demographic factors may influence individuals and social systems. CCI seeks understand how communication about climate change and about climate science may be tailored to motivate engagement in climate change mitigation and adaptation at multiple levels.

***What are the linkages with other Grand Challenges in this plan?***

Enhanced science communication creates and supports conduits for communicating about the work of the other Grand Challenge themes with the people of Maine and beyond. Goals include:

* Ensure that information about CCI, Climate Futures, and climate science in general is communicated effectively and in timely ways to audiences that need it to make informed decisions.
* Enhance learning about climate and climate science in K-12 and informal learning institutions by making information about climate research, data and model products (e.g. Climate Reanalyzer) available and accessible for teaching and learning.
* Facilitate opportunities for public engagement in research and decision-making about climate and ensure that climate-related data and information are communicated in accessible forms.
* Pursue research that explores how individual and societal-level attitudes, values, and perceptions may influence understanding of and engagement in climate change-related behavior. Ensure that Maine’s citizenry -- students, K-12 teachers, businesses, policy makers, and others -- know what the Climate Change Institute is and does, and are well informed about our rapidly changing climate, its consequences, and effective strategies for adaptation and mitigation. Social science research helps us better understand how various audiences may respond to information so we can communicate most effectively about climate change.

***What are the priorities for action over the next 5 years?***

* Coordinate and collaborate with other UMaine and UMS academic departments and research centers to provide or enhance climate-related learning opportunities for K-12 students and teachers.
* Build CCI capacity to research effective strategies and best practices for communicating and teaching about climate and climate science, in partnership with other units on campus.
* Improve CCI’s strategic use of its website, social media, outreach tools (such as the Climate Reanalyzer and 10Green) and other communication tools to reach a wider public and to support learning in K-12 classrooms.
* Engage and support CCI graduate students in experiences that involve public outreach and communication about climate. (For example, IGERT program for science communication, incorporate a service-learning requirement (following the UMaine Community Engaged Learning initiative) for CCI graduate students for which they would engage in classrooms, the 4-H Follow-a-Researcher Program, or other forms of public communication.)
* Offer resources for CCI faculty to improve their ability to communicate effectively with legislators, consistent with UMaine policy (e.g., workshops, mentor programs).
* Develop a program or certificate in Climate Science Communication.
* Coordinate a special issue of [*Environmental Communication*](https://www.tandfonline.com/loi/renc20)(CCI-affiliated faculty Nisbet and Rickard are Editor and an Associate Editor, respectively) focusing on communication-related research conducted by CCI faculty and graduate students.

**VI. BIG DATA**

***What does ‘Big Data’ mean?***

Using interdisciplinary teams and innovative technologies to integrate diverse physical, chemical, biological, and social data to solve climate-driven complex problems.

***What are the linkages with other Grand Challenges in this plan?***

Computer software has always been part of the scientific toolbox at the CCI. Computer tools have helped to advance the interdisciplinarity of the research program by unifying climate data sets from various research disciplines. Over the years a number of cutting-edge software packages were developed by CCI researchers and collaborators that genuinely extended research into the global scientific community, and provided connections with stakeholders and the general public. Some examples of these successes include: University of Maine Ice Sheet Model (UMISM), 10Green, IceReader, Climate Reanalyzer, and Visualization Wall (vWALL). To expand and amplify accomplishments and maintain research leadership, it is crucial to continue nurturing a culture of close integration of emerging computer tools and technologies used by various research areas.

***What are the priorities for action over the next 5 years?***

In the past, CCI researchers have successfully attracted external funding to develop and build new tools and to purchase transformational analytical equipment such as CCI’s WM Keck Laser Ice Facility. To continue this path of innovation it is important to support routine maintenance operations, so that efforts can be devoted to building new research systems. Computer support at the University of Maine is inadequate for the commonly unique, highly customized systems necessary for pioneering research solutions. Another important and currently underdeveloped research area is one specific to scientific computing literacy. This can be improved by offering computer programming education for graduate students and by exposing faculty to cutting edge use of computer technologies. CCI’s affiliation with the University Corporation for Atmospheric Research (UCAR) creates a unique opportunity for learning and adapting for all participants.

Finally, there is recognition that new Artificial Intelligence (AI) technology is already impacting our lives, changing the way we work and communicate. AI is modifying the landscape of commercial use of computers and clearly will benefit the “Future Science”. Earth’s past, present, and future climate research areas are a relatively unexplored area for AI tools. CCI is uniquely positioned to test and adapt this new emerging technology to pre-emptively assist future needs in “Big Data” use. It is not clear at this time what is needed and how this new research frontier in the computer science domain can be used, but we have to invest time to look and learn so when opportunities arise, we are fully prepared.

**INTEGRATED RESOURCE NEEDS**

The following resources describe the most essential needs for the agenda described above. Many components of the plan build on the strengths of CCI in research to address the growing needs to enhance outreach to public and private constituencies. Some needs will benefit from being funded through shared relationships with other units on campus.

**Priority Staff Needs**

* Base funding for Communications/Outreach/Science Writer
* Base funding for part-time Computer Systems Administrator

**Critical Tenure Track Faculty Needs (some co-sponsored with academic units)**

* Tenure track Maine State Climatologist. This position will interact with Maine stakeholders, facilitate collaboration between CCI, Cooperative Extension, NOAA, and the NWS, undertake climate modeling research, and oversee the development and expansion of CCI Big Data analysis and visualization tools. The likely academic unit and tenure home for this position is the School of Earth and Climate Sciences (also builds on existing support, and has potential for shared position with a second academic unit).
* Tenure track Marine Geologist emphasizing coastal erosion/policy. The likely academic unit and tenure home for this position is the School of Earth and Climate Sciences (reflecting imminent J. Kelley retirement).
* Tenure Track Paleontologist/Zooarchaeologist (with specialization in the Arctic, coastal/marine systems, or fauna of the Americas, reflecting loss of expertise and unit strengths in coastal zooarchaeology, Arctic/Subarctic archaeology, and the paleoecology and human history of the Americas).
* Tenure track Aquatic Geochemist/Paleolimnologist (reflecting S. Norton retirement)
* Tenure track Permafrost Scientist (expertise specifically in permafrost field or remote sensing research, numerical modeling, and/or biogeochemistry processes)
* Tenure track Social Scientist (human dimensions of changing Arctic). This position will support decision-support science, climate adaptation, outreach, and service aspects of CCI. The likely academic unit and tenure home for this position is the Department of Anthropology (reflecting imminent J. Roscoe retirement).

**Graduate Student Resources**

* Additional graduate student assistantships

**Additional Faculty/Scientist Needs for Grand Challenges**

Climate/Earth Systems Modeler: This position supports the overall goals of the *Climate Futures* “Grand Challenge” by providing capability to conduct modeling research across multiple systems and timescales, and by bridging the gaps between modeling, theory, observations, and societal implications of climate and environmental change. This position will integrate with CCI physical climate, modeling, and Big Data research projects, and also strengthen ties between CCI and the NCAR/UCAR research community. In particular, this position will run coupled atmosphere-ocean global climate simulations, which is not yet undertaken at CCI. The likely academic unit and tenure home for this position is the School of Earth and Climate Sciences.

Atmospheric Scientist/Meteorologist: This position supports the overall goals of the *Climate Futures* “Grand Challenge” by providing expertise for developing a program of quantitative climate and weather research. Focus areas may include climate extremes, Arctic and ocean dynamics, tropical-extratropical interactions, and alpine weather and climate. Research in this regard may utilize the Weather Research and Forecasting (WRF) model. This position will integrate with CCI physical climate, modeling, and Big Data research projects, and strengthen ties between CCI and the NCAR/UCAR research community. This position will also help provide critical mass for attracting new students to CCI’s growing research capacity related to Big Data and modeling. The likely academic unit and tenure home for this position is the School of Earth and Climate Sciences.

**Additional Resources**

* JIRP is a costly program for students to attend and the infrastructure requires consistent upkeep. NSF, NASA, and other federal funding agencies do not traditionally fund such maintenance and operational costs. Ultimately a goal of operating JIRP through a well-funded endowment will ensure it is sustained for decades into the future. Partnering with the UMaine Foundation to build a $5M endowment over the next 5-10 years should be a significant goal because it will provide major financial long-term benefits for UMaine students, faculty, and research activities.
* Faculty incentives for outreach and decision-support. Both are difficult to support through traditional federal research grants.
* Computing and data storage capacity (both in-house and external such as the UM Advanced Computing Group - ACG or UCAR/NCAR). Customized computer systems with dedicated hardware are required in order to study and improve the performance of algorithms for advanced big data processing to avoid possible confounding effects of virtual hardware and storage infrastructure. The expected expansion in data and computing capacity for the custom built research- and production-level systems will require additional technical staff both within CCI and in related groups such as ACG and the wider UM IT organization with expertise in designing and maintaining computer systems with flexible and highly customizable hardware and software.

**APPENDIX A**

