Research Strategic Plan Discussion Document

Research Strategic Planning Committee
October 14, 2008 version

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Research Strategic Plan

- Our 1998 research strategic plan can provide a launching point for the refreshed plan.
- We will get feedback assessment on our 1998 strategic areas.

  Research strategic areas in the 1998 plan:

  - Information and Communication Technology
  - Environmental Science, Engineering, and Policy
  - Biotechnology and Health Policy
  - Fine Arts and Humanities

What is the Purpose of a Strategic Plan?

Some examples might include:

- To strategically position the university in cross-cutting areas of research.
- To help to produce marketing themes for the capital campaign that could lead to new resources.
- To provide information to the campus on new and continuing interdisciplinary research initiatives being pursued by the units. Such information could help to create expanded collaboration.
- To explore areas where Carnegie Mellon can have a disproportionate impact, despite its size.
- To reassert the importance of foundational research and the fact that foundational research is the basis for all discovery and technology.

How is a Strategic Plan Implemented?

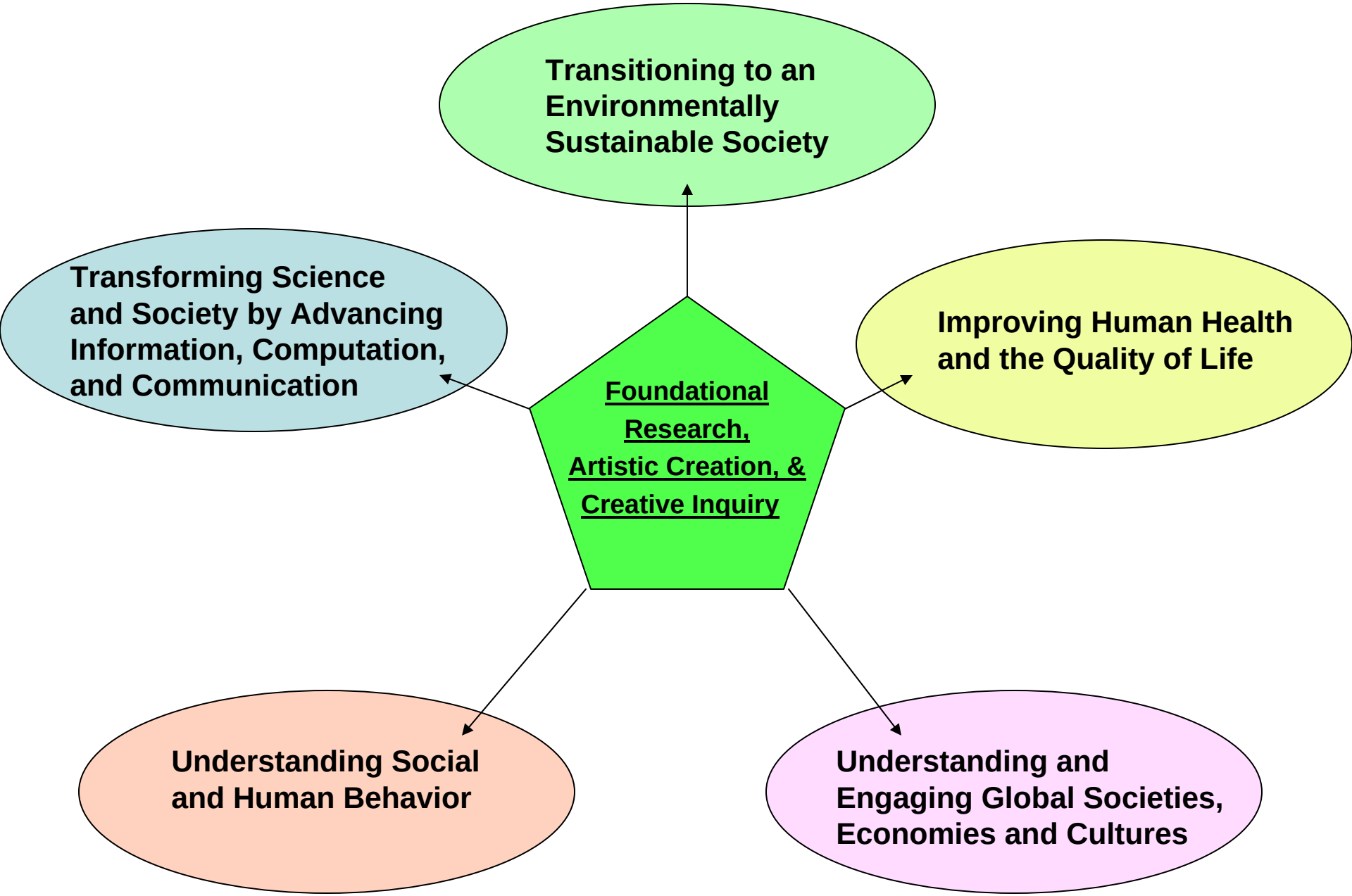
- Faculty hiring within units, such as designation of field, area, etc.
- Departments and units building capacity through research initiatives
- Leadership by president, provost, vice president for research, deans, department heads, center directors in setting strategic priorities at the subunit level
- Coordinated planning efforts among senior administration, colleges, and departments and associated mechanisms such as Presidential Advisory Boards
- Decisions regarding academic program offerings
- Space allocation decisions
- Efforts and success at obtaining external funding for research
- Increased philanthropic support
- Government relations thrusts
- Entrepreneurial efforts by faculty “champions” and academic units

2008 Research Strategic Plan

- Characteristics of our research strategic positioning might include:
  - Research areas should be important and emergent.
  - Research area should be interdisciplinary and help to connect campus units together, i.e. using collaboration to have a larger impact than our size.
  - The research areas should leverage off our current strengths by focusing on areas of comparative advantage, e.g., where we can make a disproportionate impact by building centers of excellence.
  - A hallmark of Carnegie Mellon research is that it generally impacts the quality of human life and can be translational in nature.
  - Themes should be marketable and matched to our current and emergent research portfolio that will drive fundraising opportunities that will help to create new opportunities for our faculty.
  - The plan should embrace the entrepreneurial spirit of Carnegie Mellon.
  - The plan should help to address structural needs

2008 Research Plan: Process

- Steering Committee to oversee entire strategic planning process-chaired by the Provost.
- Research Strategic Planning Committee: chaired by Rick McCullough, comprised of 18 committee members from all colleges and the Library.
- Committee had its first meeting on Monday, November 26 and has had 6 meetings to date.
- To date, I have had 60 individual stakeholder meetings with the provost, 9/10 deans, 20/24 dept. heads (5 dhs on committee), faculty senate chair, etc.
- Committee members have met with faculty group in their units to get feedback for the committee, e.g. SCS, Psychology, Tepper, etc. Committee members will be meeting with faculty groups in the units over April and May. Many more meetings with provost and deans planned.
- There is a “Quantitative Social Sciences” subcommittee co-chaired by Steve Fienberg & John Miller that contains H&SS, Heinz, Tepper and CFA committee members from the planning committee.
- Input from many campus leaders, board of trustees, town meetings, and faculty members in March and beyond.
- Final approval of the plan at the October board meeting.


Transitioning to an Environmentally Sustainable Society
Transforming Science and Society by Advancing Information, Computation, and Communication
Improving Human Health and the Quality of Life
Foundational Research, Artistic Creation, & Creative Inquiry
Understanding Social and Human Behavior
Understanding and Engaging Global Societies, Economies and Cultures

The University strategic plan reaffirms the critical role of foundational research in the arts and humanities, engineering, the behavioral and social sciences, and the mathematical and natural sciences in the university mission and in enabling targeted strategic thrusts.

Emerging Themes-ICC

Information, Computation, and Communication

- Cyber-enabled Scientific Discovery

  There are early yet compelling signs that a new mode of scientific discovery is emerging. The classical research process involves cycles of observe-hypothesize-experiment-and-interpret. Now researchers can complement this approach by taking advantage of our ability to obtain, generate, manipulate, and analyze massive amounts of data and thus glean new possibilities for the advancement of science and engineering.

  - Machine learning
  - Computational biology
  - Autonomous science
  - Analysis of large data sets and data mining
  - Simulation and modeling
  - Computational Engineering, Chip Design, and Materials
  - Computational Design

CMU's strengths in computing, machine learning, biotechnology, and autonomous robotics make it uniquely positioned to lead in this development.

Emerging Themes-ICC

- Next Generation Computing

  Computing is entering a new era of “big cycles, big data, and big users.” This step is driven not only by the massive movement of scientific and engineering research to large-scale, data-intensive modes of discovery, but also by the increasing dependence of business and other decision-making on large-scale data analysis and mining.

  In the next decade, the top universities in computing research will be defined, in large part, by their leadership in large-scale, data-intensive computing. CMU must take on this theme to maintain its lead in computing research.

  - Synergies with next-generation scientific discovery
  - Large scale data storage/Parallel data lab
  - Data storage technology
  - Data-Intensive scalable computing
  - Machine learning
  - Cosmology
  - Language technologies
  - Secure and trustworthy computing infrastructure
  - Modeling complex natural and engineered systems
  - Sensed and intelligent infrastructure

Emerging Themes-ICC

- Arts →Technology and Technology → Arts

  New technologies are interesting not only because they can be used to solve problems, but also because they enable the possibility to expand or create new modes of human experience. For example, the interactions between the visual arts and state-of-the-art vision processing may enable new forms of interactive media which in turn may allow or force us to engage in new ways of thinking.

  Carnegie Mellon has achieved a “critical mass” of artists and technologists in this domain, spanning many of its academic units. This theme is also synergistic with the drive towards research in the fine arts.

  - Interactive media
  - Computer music
  - Motion Capture in Animation
  - Entertainment Technology
  - Social robotics

Emerging Themes- ICC

- Society-Scale Computing

  The widespread adoption and use of information technology at a societal scale has led to both new problems and new opportunities that arise at the intersection of technology and social science. CMU's interdisciplinary strengths in computer science, engineering, information systems and social sciences will lead to innovative breakthroughs in areas such as:

  - IT-enabled communication for commerce, politics, social networking, and health
  - Computational Marketing
  - Information Privacy and Security

Emerging Themes-ICC

Technology Enhanced Learning

Emerging Themes

Transitioning to an Environmentally Sustainable Society

Energy and the Environment

- World energy production increased more than 40% between 1980 and 2000, and continues to grow at a rapid rate. The physical limits, national security dilemmas, and environmental impacts of fossil fuels are now clear. New technologies and national policies are needed for bold new directions. Carnegie Mellon is positioned to contribute significantly in:
- Sustainable Energy Production
  - Advanced materials and processes for renewable energy, e.g. solar
  - Clean coal technologies; carbon capture and storage
  - Future power systems: operation and control
- Energy and Climate Protection Policy
  - Regulatory incentives; market tools
- Energy Efficiency and Demand Reduction
  - Green product and process design
  - Computational green design
  - Green architecture/Sustainable buildings

Emerging Themes

Transitioning to an Environmentally Sustainable Society

Urban Infrastructure and Sustainable Cities

- By 2008, more than 50% of all people will live in urban areas. Urban population will grow to 4.9B by 2030 and 6B by 2050 (2/3 of projected total global population). The current pace and scale of urban growth strains the capacity of local and national governments to provide or maintain basic services, and generates unsustainable burdens on the environment. The problems are especially acute for the megacities of the developing world, but are also significant for the developed world.
- Integrated social-engineering-economic approaches driven by a systems perspective are critical for the quality of, literally, billions of lives. Carnegie Mellon is positioned to lead in developing such approaches that consider:
  - Environmental quality and health
  - Next generation technology for water infrastructure
  - Restoration of water and land, e.g.
  - Improved infrastructure life
  - Green architecture and new paradigms for remaking cities
  - Sensed and intelligent infrastructure
  - Sustainable chemistry and nanoenabled remediation

Emerging Themes

Biotechnology and Human Health

Recent developments in deep sequencing technologies, high throughput instrumentation, machine learning approaches, and nanotechnology presage an era of dramatic advances in improving human health. Particular opportunities for new advances drawing on Carnegie Mellon's interdisciplinary traditions exist in many areas, including

- Computational biology and autonomous science
- Neural computation
- Mind-Body Science
- Molecular and cellular mechanisms underlying human disease
- Medical robotics, biosensors, and nanobiomaterials

Emerging Themes - ICC/Biotech

Computational Biology

- Biology has been revolutionized by automated methods for generating large amounts of data on diverse biological processes. Transition from paradigm of detailed study of single molecule or event to paradigm of comprehensive, systematic studies combined with computational data analysis. Need integration of information on many aspects to construct detailed, predictive models, but complexity suggests models be constructed automatically. Requires iterative cycles of acquisition, analysis, modeling, and experimental design, since it is not feasible to do all possible biological experiments. Examples of areas involved and impacted are
  - Genetics, genomics, virology
  - Biochemistry, physiology, metabolic diseases
  - Cell biology, cellular biomechanics, cancer
  - Neurobiology, stem cells, tissue engineering
- Carnegie Mellon is already playing a significant role in this field, and has especially pioneered approaches to areas such as bioimage informatics and network inference. Carnegie Mellon is a world-leader in machine learning, and experimental science is a learning process. The Lane Center for Computational Biology has been created as a focus of a university-wide effort to pioneer development of active learning approaches for automated creation of detailed, predictive models of biological processes and thereby catalyze the next revolution in biology.

Emerging Themes - Biotech

Mind-Body Science

- Mind-Body Science seeks to determine the basic biological and genetic pathways that translate psychological, social, and behavioral forces into disease across the life span. The psychosocial and behavioral factors of interest to researchers (e.g., stress, smoking, obesity, lack of meaningful work and economic opportunity) are estimated by the Centers for Disease Control to account for 50 percent of mortality for the 10 leading causes of death and for a substantial portion of health care costs. Topics within this area include:
  - Immunology, virology, and medicine
  - Gene-environment interactions
  - Quality of life and health
  - Developmental antecedents of adult disease
  - Interventions to facilitate adjustment to chronic disease
- Addressing questions related to Mind-Body Science requires a multidisciplinary approach and stands at the interface of individual behavior, socio-cultural context, and human biology. The core faculty are already in place, and the intellectual environment at CMU provides a unique framework to enable this field of research to develop quickly.

Emerging Themes - ICC/Biotech

Neural Computation

Interface between brain and computation

- The brain and nervous system are amazingly adept at information processing. A developing field of inquiry seeks to understand the mechanisms and principles underlying neural computation by applying techniques from a wide variety of disciplines including computer science, statistics, mathematics, and physics. The theme of neural computation combines the quest for quantitative understanding of function and malfunction of the nervous system with an over-arching aim of discovering successful computational strategies. Topics within this area include:
  - Neurally inspired intelligence, algorithms, and adaptive computing
  - Neural, statistical, and machine learning
  - Brain-machine interface
  - Cognitive robotics and cognitive tutors
  - Computational principles of perception
- This initiative draws on CMU's strengths in computational and cognitive neuroscience, cognitive psychology, computer science, statistics, machine learning and robotics.

Emerging Themes - Biotech

Molecular and cellular mechanisms for human biology and disease

•Increased availability of genome sequences for many organisms have created new opportunities for understanding the fundamental processes that govern formation of embryos and generation of body parts for all animals. Thus comparison of pathways across organisms provides new insights previously unavailable. Knowledge of fundamental molecular and cellular mechanisms can and often is revealing of the basis of human disease. When combined with computational analyses, and eventually, personal DNA sequences, this should result in personalized medical treatments. Particular opportunities exist for

- Understanding formation and function of subcellular compartments and membranes
- Understanding the structural, catalytic, and regulatory roles of nucleic acids and their potential for creating new tools as diagnostic or therapeutic reagents
- Understanding the molecular and cellular mechanisms in cognition and development of the nervous system
- Understanding the signal transduction pathways and the genetic regulatory networks in developing embryos
- Developing bioimaging and imaging informatics

• Carnegie Mellon has remarkable interdisciplinary strength in biomedical research drawing from many departments and colleges. Of particular note is significant strength in RNA biology and chemistry, embodied in the recently created Center for Nucleic Acids Science and Technology.

Emerging Themes - Biotech

Biomedical robotics, biosensors, and nanobiomaterials

•Robotics overcomes limitations in human capacity, and allows the execution of complex experimental or medical procedures at a high precision, speed, and redundancy. The applications will likely expand to a wide range of basic biomedical research, diagnostic, and medical/surgical operations. Potential areas of development include automated/adaptive optical imaging and tomography, micromanipulations and microsurgeries, intervention radiology, artificial organs and smart implantable medical devices.

•Nanotechnology is finding increasing applications in biomedical research and medicine, due to the growing recognition of the importance of precise regulation of chemical, mechanical and topographical parameters for cells and tissues. In addition, smart materials may respond to the environment, thereby serving as powerful sensors or manipulative tools. Potential directions include new biosensor materials for probing the behavior of normal and diseased cells, materials for manipulating stem cell differentiation, materials for promoting tissue formation, and implantable materials for controlling cancer, trauma or spinal cord injury.

•Carnegie Mellon is already leading in some of these areas, including biosensor development (MBIC), medical robotics (MRCAS), and there has been significant faculty development in the area of nanobiomaterials. Strengths in bioimage informatics and computational biomechanics could be synergistic with this theme.

Social and Behavioral Sciences

- Carnegie Mellon has a long history of transformational research in social and behavioral sciences. Academic fields have been redefined by creative moves across disciplinary boundaries in a quest to understand the complexities of human behavior and social systems that are not bound by disciplinary conventions. Carnegie Mellon faculty are continuing this tradition by exploiting advances in computational methods and innovative approaches to experimentation to impact our understanding of social and behavioral systems.
- Three emerging strategic themes in this area are:
  - Understanding Complex Social and Behavioral Systems
  - Understanding Impact of Technology on Social and Economic Systems and the Management of Technical Innovation
  - Translational Social and Behavioral Sciences

Emerging Themes-SBS-1

Social and Behavioral Sciences:

Understanding Complex Social and Behavioral Systems

- The social and behavioral sciences are in the process of restructuring across disciplinary boundaries, as they seek a deeper understanding of the complexity inherent in social, behavorial, and economic systems. This quest emanates from commonalities across domains and exploits advances in computational power, experimentation, and communication. It is reflected in ongoing research in such diverse domains as:
  - Behavioral decision research
  - Cognitive, developmental, and social neuroscience
  - Cognitive and learning science
  - Organizational learning and adaptation
  - Computational social sciences
  - Network modeling
  - Strategy, entrepreneurship, technology change, and innovation policy
  - Decisions, Transactions and Outcomes in Dynamic Uncertain Environments
- Carnegie Mellon's research traditions in the social and behavioral sciences and its embrace of computational methods in science ideally positions us for advances in this area.

Emerging Themes-SBS-2

Social and Behavioral Sciences:

Understanding Impact of Technology on Social and Economic Systems

The deployment of transformative technologies in social and economic environments has resulted in new issues in the design and use of such systems and also new opportunities for decision making and problem solving. Innovative models for such emerging phenomena may result in groundbreaking paradigms in wide ranging research domains including:

- Behavioral and computational economics and finance
- IT-enabled Services: Organization, incentives and optimization
- Privacy and security
- Simulated marketing environments
- Stochastic optimization of supply chains

CMU's tradition of building fundamental models of social and economic systems combined with familiarity in designing and deploying some of these technologies put us in a unique position to pursue this area.

Emerging Themes-SBS-3

Social and Behavioral Sciences:

Translational Social and Behavioral Sciences

As knowledge of social and behavioral processes increases there is need to apply that knowledge to solve real-world problems, as well as to provide interventions that are designed to enhance the quality of human life in the following areas:

- Behavioral medicine and health policy
- Behavioral social policy
- Educational and instructional innovation
- Mind-body medicine
- Cognitively and behaviorally driven design for engineering and technology
- Behaviorally informed regulation and public policy
- Understanding typical and atypical development
- global economics, politics and technology
- Groups and organizational performance
- Learning and social interactions in markets and organizations

- CMU's tradition of trans-disciplinary research and collaboration and its institutional focus on the application of problem solving for social improvement provides the needed context for this research thrust.

Emerging Themes

Knowledge building through creative inquiry

- Artists, designers, performers and humanists in Carnegie Mellon play the role of creative catalyst merging the poetic and pragmatic with visionary versatility.
- Their work reflects current issues, challenges societal restrictions and mores, sometimes, in the process creating beauty,order or aesthetic, demonstrating the inherent chaos of contemporary life, addressing government decisions or posing philosophical questions.
- They are visionaries, provocateurs, and iconoclasts who imagine the future, who question the direction of humanity, who are able to synthesize the constantly changing technology, viewpoints and culture through their creative inquiry.
- Innovation flourishes when disciplines come together, and Carnegie Mellon is in a unique position to bring together the creative potential of the arts, humanities and sciences to support and complement each other. We expect to develop different models that support best practices in creativity and innovation, which can then be replicated and scaled in other domains.

Emerging Themes

Knowledge building through creative inquiry

Particular areas of interest are:

- ***The arts and technology/culture and computing:*** Understanding this bi-directional relationship is central to the evolution of our society. The impact of new technologies on the making, distribution, experience and reflection upon cultural artifacts and events has been profound. The influence of the arts in charting new territories for technological exploration is key to current innovation models. Design and performance technologies have increasing cross- and inter-disciplinary impact.
  - Interactive, tangible and mediated design
  - Sustainable design and technologies
  - Technology enhanced production and performance
- ***Environment, landscapes, urbanscapes:*** Addressing issues of interconnected-ness between the natural and built environments in order to shape a sustainable future where technology, culture and nature coexist in symbiosis, is a challenge that will define our legacy for future generations.
  - Contextual Practices
  - Re-imagining Cities
  - Cluster research in arts and publics
  - Cultural Industries

Emerging Themes

Knowledge building through creative inquiry

Support initiatives and infrastructure:

- To support the societal impact of this work, a new space for experimental inclusion (a true "invention crossroad") is proposed, where creative and performing artists, technologists, engineers, humanists, scientists, policy makers can meet and collaborate; a place where links are developed between innovative thinkers and organizations to build powerful partnerships to strengthen and foster creativity.

- Artistic creation and humanistic output, ultimately, are expressions of culture. Their practice and productions are represented at the highest level in Carnegie Mellon. We propose that a high-level committee be formed to explore present and future strengths, collaborations and needs in these areas.

Emerging Themes (in progress)

Global Societies, Economies, and Cultures

Globalization is an important research theme in many Carnegie Mellon Colleges. Emerging strategic themes in this area are:

- The human side of globalization
- Understanding and engaging in the emerging global economy
- Understanding international political relationships and structures

Emerging Themes

Global Societies, Economies, and Cultures

The Human Side of Globalization

- Understanding the globalization of culture and citizenship
- Understanding the role of agents in global communication
- Connecting local and global histories
- Supplementing traditional humanistic research with data mining and automated discovery applied to scholarly databases

Emerging Themes

Global Societies, Economies, and Cultures

The Economic Dimension of Globalization

- Identifying the components of economically successful innovation and technological change
- Designing and managing global supply chains
- Bringing technological change to underdeveloped and emerging economic powers

Fundraising Themes

- Computer Science as a defining direction for society
  - Computer Technology to Address Global Issues: Human Health, Economic Development, and Education
  - E-Science and Autonomous Science and Technology
- Quality of Life, or Human Health and Welfare and Sustainability
  - Cancer
  - Early Disease Detection
  - Disease diagnostics
  - Artificial organs
  - Behavioral medicine
  - Human Centered Science and Technology
- Energy and Sustainability
  - Advanced materials and processes for renewable energy
  - green design; green buildings
  - Climate protection and policy
- Urban Infrastructure and Sustainable Cities
  - Air quality and health
  - Next generation technology for water infrastructure
  - Green architecture and new paradigms for remaking cities
- The Global Technological Economy
- Artistic Creation and Inquiry
- Expanding Education in the the 21st century
- Social Sciences - Thinking
  - Mind and Body
  - Brain and Mind
  - Decision Making in Individuals and Organizations
  - Typical and Atypical Human Development

Assessment

- As part of the process, the committee and stakeholders to date have attempted to assess our 1998 Strategic Plan in the preparation for the new plan.
- Assessment has included exploring questions, such as:
  - Did the plan help to guide creation, growth, and building of core areas of strength and emerging of new areas of strength for CMU?
  - Did we build new areas of strength?
  - Did the strategic research areas help us in fundraising?
  - Were our rankings in any departments are disciplines affected by our strategy?
  - Did our plan help in recruiting and retaining our great faculty?
  - Where did we fail or plateau in the plan? Why?

The 1998 Plan

- The 2002 Information Technology Strategy from the planning document and the 2002 Board Presentation

Shared set of premises: 1. Broad and visionary, 2. Focused and executable, 3. Build on our strengths, and 4. Pass the “who cares”, “so what” test.

- Areas that emerged and examples of initiatives
  - Enhanced human learning and performance
    - Automous and medical robotics, HCII, ubiquitous computing
  - Education
    - Cognitive tutors, intelligent assistants, authoring tools
  - Security and dependability
    - Cybersecurity, mobile computing, dependable computing, networking
  - Bioinformatics and computational modeling, simulation, and control of biological and other complex systems
    - Computational biology, multiscale modeling, imaging, complex systems
  - Impact of IT on Society
    - E-democracy, privacy, digital libraries

The 1998 Plan

- 1998 Environmental Research Strategy – faculty committee
  - Expand Green Design Initiative
  - Expand energy-related environmental research in CIT and Architecture
  - Expand Green Practices Program; use campus as test facility
  - Expand research on innovative, smart environmental regulation
  - Establish Carnegie Mellon Forum on the Environment (Kennedy School model)

- 2002 Environmental Research Strategy- Trustee and Faculty committee
  - Energy and the environment
    - Electricity, energy for transportation issues, renewable energy production, energy efficiency.
  - Urban Infrastructure
    - built and natural environment (buildings, highways, water supply and wastewater systems, airsheds, watersheds).

The 1998 Plan

- <u>The 1999 Biotechnology Research Strategy-from the planning document and a 2006 presentation to the Board of Trustees</u>
- Areas and action items that emerged
  - ✓ computational biology and chemistry
  - ✓ neurobotics and elder-focused design
  - ✓ proteomics
  - ✓ behavior & health
  - ✓ establish BME Department
  - ✓ neurobiology
  - ✓ neuroscience imaging facility
  - ✓ health policy/economics and health informatics
  - ✓ hire life sciences coordinator
  - ✓ provide seed funding for interdisciplinary collaborations
  - ✓ expand interdisciplinary life sciences education programs
  - ✓ hire biochemistry faculty
  - ❖ tissue engineering
  - ❖ create external advisory board
  - ❖ create biomedical data repository

❖ means-not a complete success or was not done
✓ means was done successfully

The 1998 Plan

- Arts and Humanities
  Center for Arts and Society
  Studio for Creative Inquiry