The Internet information infrastructure is poised to undergo several fundamental transitions during the next decade. Explosive growth of digital wireless Internet channels will connect vast numbers of mobile end points (information appliances, sensor arrays, and embedded processors) to the fixed Internet components, at the same time tens of millions of households and businesses will move from modems to broadband connections. This confluence of trends will require the Internet’s fiber backbone to carry highly parallel wavelengths of light. As David Nagel, President of AT&T Labs, says in his supporting letter, “Here at AT&T, we believe the next-generation information infrastructure will change our lives in ways we can’t imagine today.”

California’s companies justly enjoy a leadership position in today’s Internet technologies and wireless mobile voice communications. However, as the “technological discontinuities” inherent in the creation of the new Internet come to pass, leadership may shift among existing companies or to companies that don’t exist today, based on products and services derived from innovative science and technology. To help ensure that California maintains its leadership in the telecommunications and information technology marketplace, UCSD and UCI have teamed, in response to the Governor’s initiative, to propose the California Institute for Telecommunications and Information Technology [Cal-(IT)^2].

Our institute’s mission is simple—extend the reach of the current information infrastructure throughout the physical world. As simple as this statement is, the research required to bring it to pass is formidable. For instance, sensing the environment and civil infrastructure continuously and efficiently requires research on materials, devices, circuits, and systems-on-chip to create a new generation of low-cost, low-maintenance, low-power nodes that can sense, store, process, and communicate data. New research on devices, circuits, and communication systems is needed to develop a common untethered communication fabric. Organizing the large-scale sensor networks demands software research on self-organization, scalability, and security.

The “new Internet” will be an integrated system. However, one of the innovative aspects of our institute is how we decompose that system into five vertically interlocking set of “layers,” each teaming academic and industrial researchers on interdisciplinary problems: Materials and Devices, Networked Infrastructure, Interfaces and Software Systems, Strategic Applications, and Policy,
Management, and Socioeconomic Evolution (Fig. 1). In Strategic Applications, we assembled four drivers—Environment and Civil Infrastructure, Intelligent Transportation, Digitally Enabled Genomic Medicine, and the New Media Arts—to foresee the long-term potential of the infrastructure’s capabilities and provide feedback to technology developers. These applications target core concerns addressing California’s quality of life and represent large market segments of California’s economy poised to be transformed by the new Internet.

We can understand the intricate interactions between applications and new Internet technologies only by deploying prototype instrumented “smart environment” testbeds, enabling institute participants to “work in the future” in a continually improving, mobile digital environment with flexible information management resources, tied together with a high-bandwidth fiber backbone. These testbeds will allow researchers to “plug in” new algorithms and experimental systems, receiving immediate feedback. Industrial partners will gain first-hand experience with product prototypes and identify, early on, new services and products that the infrastructure will require. Students will learn in this powerful, dynamic environment and, upon graduation, become the leaders of the next generation of research and development in academia, industry, and government. Policy makers and business management experts will have the opportunity to study emergent issues in this “living laboratory.”

No single investigator could hope to study this emerging system in its entirety, nor does any single company have sufficient resources to dominate the corresponding market. Our institute, by contrast, because of our organization and vision, expects to make a significant impact. We will work at the frontiers of the new Internet telecommunications infrastructure at least 3-5 years ahead of commercial practice, yet tightly coupled to long-term basic research that will lay the foundation for products 5-10 years into the future.

In short, the whole of our institute is more than the sum of its parts. As the CEO of the pre-IPO startup Silicon Wave says in his supporting letter: “We are excited about the innovative approach being taken in assembling a team of researchers spanning from device physics to applications to policy. In fact, we see this aspect of your institute as bringing a unique new capability to California.”

As our proposal cover shows, our institute spans the “High Tech Coast,” home to a concentration of telecommunications and information technology companies that most agree will be the site of the major economic growth in California over the next 10-20 years. We have partnered with many companies in this area and with leading companies in Silicon Valley and elsewhere in California and the U.S. to ensure our institute will have a continuing impact on the State’s economy. Industrial partners strongly support this plan as shown by their commitments already in excess of $139 million. In addition, we have firm pledges of $32 million in foundation and individual gifts and $30 million in Garamendi cost sharing, and expect $56 million in federal grants over the next four years based on our demonstrated track record in recruiting federal research grants (Sec. C). This totals $201M committed and $257M in projected matching funds.

**Organization by Science and Technology “Layers”**

Over the last nine months, starting from our central theme of the new Internet, we have deconstructed the theme into its subcomponent layers, searched out and engaged some 200 UCSD/UCI faculty and research professionals (identified by team in App. A), and developed partnerships with 28 key companies identified in Sec. F. Each team has, from the bottom up, chosen its “layer leaders” (App. A) and engaged in many group meetings, which, over time, has resulted in the research plan described below. Each layer is integrated between campuses and with our industrial partners, but, in each case, leadership is clear. The result is a new “critical mass” of collaborating researchers in each logical layer, built from excellent individual researchers, most of whom were not collaborating with each other prior to our team building process. We have carefully designed many “vertical” links between layers so as to make a “supercritical” interacting whole. Significantly, many of the faculty
members have commented that this process has started “changing the culture” of the campuses toward a more cross-disciplinary approach. Without the Governor’s initiative, it would have been essentially impossible for a systems-integrated approach on this scale focused on serious California problems to have come into being.

1. Materials and Devices

Materials and device technologies developed over the past few decades have provided the foundation for the current explosion in computing systems, wireless communications, and optical networks. For example, fiber-optic capacity has increased over the past decade from 10 to 3000 Gbps because of doped fiber amplifiers, semiconductor lasers, high-speed optical modulators, wavelength filters and routers, and high-speed devices for associated electronic circuits. Similarly, breakthroughs in materials and device technology have the potential to enable dramatic advances in the new Internet telecommunications systems (Fig. 1).

![Diagram of advanced materials and devices](image)

**Figure 2:** Advanced materials and devices play an essential role in all parts of the new Internet.

Further increases in optical network capacity will depend on new materials and device concepts, based on nanoscale design and engineering of photonic materials, ultra-small device structures such as thresholdless lasers, and micro-electro-mechanical systems (MEMS) for compact optical components. Wireless, high-speed, handheld access to the Internet will require new ultra-low-power, high-speed transistors and advanced materials and processing. Industrial partners AMCC, Broadcom, Conexant, Ericsson, IBM, and Intersil will be involved closely in our projects.

Cal-(IT)² will create experimental facilities (Sec. D4) to enable research in four critical areas:

- **Materials and devices for wireless communications:** This effort will focus on (1) ultra-low-power devices operating at frequencies of several GHz to >100GHz based on advanced semiconductor heterostructures, devices scaling to nanoscale dimensions, and novel materials for gate insulators, contacts, and packaging; (2) high-power microwave transistors for wireless network infrastructure based on wide-bandgap semiconductors such as GaN; (3) novel integrated materials based on wafer bonding, hetero-epitaxial growth, and self-assembly for advanced electronic device, passive components such as inductors, capacitors, and resonators, and efficient systems integration; and (4) spintronics for nonvolatile, high-density memory and very-high-
frequency microwave filters. This work will be led by UCSD and work with Networked Infrastructure (next section).

- **Materials and devices for photonic networks:** We will develop highly tunable, multi-spectral light sources, advanced receivers, wavelength converters, optical amplifiers, dense wavelength division filters, and high-speed optical switches and routers based on advanced semiconductor heterostructures, micro-electro-mechanical systems (MEMS)-based components, and nanoscale engineering of optical properties of materials and devices. These components will enable transmission of information at speeds an order of magnitude or more higher than current technology in land-based optical communication systems, with scalability from long-haul to chip-to-chip optical links enabled by nanoscale design and fabrication (Fig. 3). This work will be led by UCSD in conjunction with Networked Infrastructure.

- **Molecular materials:** We will develop sensors and switches with ultra-high sensitivity, chemical and/or biological specificity, fast response, and ultra-low-power consumption from molecular and hybrid polymer materials easily fabricated to any shape and at very low cost. This effort will be led by UCI, with the development of biochip sensors led jointly by UCI and UCSD. We will work with the applications teams to develop implantable biochips for in vivo monitoring of blood chemistry, combined with wireless telemetry for data collection and offline analysis, implantable systems for feedback-controlled drug delivery, and wireless, self-powered environmental (chemical/biological) sensors to monitor California pollution.

- **Micro-Electro-Mechanical Systems:** Communication system-on-a-chip and medical diagnosis lab-on-a-chip are essential for future wireless medical devices. Here we will focus on integrated (amplifier and filter/switch) devices and bio-compatible polymers, and bio-MEMS fabrication processes to create disposable bio-chips for the Environment and Civil Infrastructure and Telemedicine applications. This work will be led by UCI. We will work with the applications to develop disposable biochips for mobile (wireless) health monitoring and drug screening and three-dimensional DNA array detectors.

![Figure 3: Nanoscale design and fabrication techniques will develop ultra-compact, integrated photonic chips for optical communication and data network systems.](image-url)
in all components of the new Internet’s networked infrastructure: digital wireless, broadband, fiber links, network architecture, protocols, management, computing, and storage. We will research and construct several large-scale prototype testbeds described (Sec. D4).

The seminal work of Claude Shannon, published some 50 years ago, established limits on reliable communication and compression, and launched the systematic study of coding, signaling, detection, classification, and compression. Cal-(IT)$^2$ researchers will study these topics in the context of ultra-high-density communication and storage of multimedia information over wireless, copper, photonic, and read-write channels. In particular, Networked Infrastructure will research advanced signal coding and decoding techniques, including “Turbo Codes,” low-density parity check codes, and newly emergent iterative decoding. We will investigate space-time codes and processing to generate order-of-magnitude increases in spectral efficiency. Future broadband wireless systems, when called upon to support high data rates over limited frequency bands, may have to operate with low processing gains and rely on spatial diversity techniques. The need to provide quality-of-service guarantees to voice, data, and other sensor traffic streams will require us to study adaptivity at every level of the protocol stack to design the communications receiver. We will also focus on novel data compression and bandwidth efficient modulation techniques. Cal-(IT)$^2$ industrial partners here will include Ericsson and Qualcomm.

Cal-(IT)$^2$ will establish a Telecommunications Circuit Laboratory, a powerful national resource to design and implement the most advanced integrated circuits for wireless and optical communications networked applications. As silicon technology drops to the sub-0.1-µm level, mobile wireless devices will require single-chip advanced radio circuits that can tune over multiple standards and self-calibrating data converters that digitize data increasingly closer to the antenna. We will investigate baseband digital processor architectures to accommodate advanced wireless multimedia applications in an energy-efficient manner. We will also investigate new circuit architectures and interface approaches that enable implementation of the optical interconnection protocols at the >40GB/s rates. Here we will work closely with AMCC, Broadcom, Conexant, Copper Mountain, Ericsson, IBM, Intersil, Qualcomm, and STMicrosystems.

Extraordinary advances are occurring in microelectronic design and integration of portable networked embedded system devices. We will focus on improving RF transceivers, radio modems, wireless link controls, cellular and Internet protocols, audio and video processing, and security mechanisms. Finally, we will improve algorithms, methods, tools, and software libraries to conceptualize and implement complex microelectronics-based systems on a chip targeted for network-embedded applications.

Ubiquitous access to the Internet from handheld wireless terminals and sensors will require research on algorithms for media access, congestion control, signaling strategies, security, resource allocation, service composition, and pricing for wireless access to the Internet using sensor-based and power-aware hardware/software. For example, UCI’s Center for Embedded Computer Systems research on “smart environments” is investigating the use of thousands of small, disposable, wireless sensor packages to “blanket” an area of interest (such as a remote environmental area). In such scenarios, power budgets/package will be so small that each sensor cannot afford the power to connect to the Internet using a cellular telephone. Instead, the sensors themselves must form autonomous, self-organizing systems in which data will be forwarded and routed through the sensor network until they “find” devices with more powerful transmission capabilities. Such self-organizing ad hoc networks will enable rapid deployment of sensing arrays in emergencies without pre-planning.

Our work building reliable networks from unreliable links will address smart media access protocols and link adaptation algorithms. We will also consider network and transport layer protocols, including TCP over wireless links and IP multicasting for wireless networks with mobile terminals. The recent emergence of competing technologies that target the unlicensed RF band could lead to large-scale, uncoordinated systems sharing a common resource. We will use our campus-wide,
wireless testbeds (Sec. D4) to investigate control algorithms to mitigate interference between large-scale distributed networking systems. Researchers from UCSD’s Dynamical Systems and Control group will study the stability of free and controlled systems together with quantification and realization of improvements achievable via feedback.

While higher microwave frequencies are expected to cater to the growing demand for wireless services, optical-fiber links in the backbone of the global telecommunication network must also scale to address future needs. We are building a strong fiber-optics group based on work in UCSD’s Ultrafast and Nanoscale Optics Laboratory and industrial partners AMCC, Broadcom, Cox Cable, Global Photon Systems, IBM, OMM, and TeraBurst Networks. We will focus on three critical scales for photonic coupling: nanoscale devices to enable highly parallel wavelength division multiplexing (WDM), short-range optical links inside and between computers and peripherals, and global WDM testbeds (Sec. D4).

Just as important are developments in widespread distributed storage. UCSD’s CMRR studies the science and engineering of magnetic materials, design and fabrication of disks and read-write transducers, and performance of mechanically engineered servo control at very small physical scales. In Cal-(IT)$^2$, CMRR will work with CWC to develop signal processing and coding methods for very low signal-to-noise ratio channels. CMRR will explore novel recording technologies based on patterned recording media, holographic recording materials, nano-scale mechanical structures (permitting storage at atomic scales), and storage architectures for mobile communications and computing networks.

With respect to computing and data analysis, Cal-(IT)$^2$ is strengthened by its partnership with UCSD’s SDSC. This, in addition to partnerships with the Los Alamos (LANL) and Lawrence Livermore National Laboratories (LLNL) guarantees our institute will have access to the world’s most advanced computational resources. Cal-(IT)$^2$ will enhance this infrastructure, focusing on data mining, visualization, distributed computing, and storage. Leveraging these resources with additional funding from Ericsson and Qualcomm, we propose to create a holistic, software-based communication testbed to simulate complete commercial communication systems. We will use it to study propagation, modulation, coding, spreading, power control, scheduling, and link and transport layer protocols.

Currently, two million homes have cable modem or DSL, and that number will jump to 30 million in the next three years. UCI’s Interoperability Lab and UCSD’s CWC are developing a strong program on next-generation broadband with industrial partners Broadcom, Conexant, Copper Mountain Networks, and Intersil. Broadband access encompasses both wireless (e.g., LMDS) and wireline services. We will pioneer the development of new applications using “peer-to-peer” distributed computing built out of broadband connections to individual PCs at homes and businesses, such as that of Entropia, one of our pre-IPO partners.

Finally, we will have a long-range basic research program on breakout technologies in telecommunications and information technology. With support from Qualcomm, IBM, and STMicroelectronics, we will investigate devices, circuits, air interfaces, and protocols for new ultra-wideband communication systems. UCSD’s Institute for Nonlinear Science will develop wireless communications devices and optical devices based on optoelectronic feedback semiconductor laser systems, which produce chaotic waveforms.

With information technology shrinking to nanometer scales over the next two decades, Cal-(IT)$^2$ has assembled a multidisciplinary group of UCSD and UCI physicists, chemists, mathematicians, computer scientists, and electrical engineers who will conduct research on quantum information processing and telecommunications. Close collaboration is underway with experts in the field at LANL, and discussions are continuing for closer ties with the Caltech group. This research will create components of a “quantum Internet.” UCSD will study the design and function of a quantum computer using techniques such as optical control of excitons in semiconducting quantum dots or control of spins in magnetic quantum dots. The design will be implemented using the institute’s Materials and
Devices nanolithography facilities to prepare systems in which quantum effects are important. UCI will use its optical and chemical laboratories to study quantum computing using nonlinear optical methods and develop 3-D optical read/write memory, the first step toward full optical quantum computers. In the long term, quantum computers may well run algorithms that simplify a wide range of computational tasks, including those required for effective and secure telecommunications.

3. Interfaces and Software Systems

Major advances in software technologies will be required to enable the “new Internet.” Areas of investigation will include large-scale ad hoc wireless networks, a secure metacomputing infrastructure, mobile agent technologies, sensor simulation, sensor network integration, and development of new middleware and human-computer interfaces. The need for innovation in algorithms to match the vast size and complexity of this new Internet, in turn, indicates that mathematical research will also play a critically important role in our institute. UCSD will take the lead in this layer with strong collaboration from UCI’s Information and Computer Science Department, Center for Networks and Middleware Information Systems, and Center of Integrated Information Technologies for Infrastructure Systems. Underlying all Cal-(IT)$^2$ software infrastructure development will be the need for security and scalability.

Security spans authentication of people and devices to integrity of data from sensor networks to methods of encryption. Wireless platforms will form the smart communications end points for users, providing interactivity and acting as secure input/display terminals. For applications in which interactivity and availability in the face of network interruptions are important, such as providing access to medical records for emergency medical physicians, secure mobile agents will act as mobile service providers for the users’ wireless devices. One of Cal-(IT)$^2$’s first security projects will be to complete and extend the UCSD Sanctuary secure mobile agent system as a wireless application security platform.

We will also examine design and implementation of a public key infrastructure to support host-security attribute certificates for security-aware migration and attribute certificates to implement role-based access control. In the real world, availability and function must be maintained in the presence of inevitable security breaches, but in large-scale environments a single global entity cannot monitor all attacks centrally. Distributed intrusion detection is needed to detect and defend against distributed attacks. Cal-(IT)$^2$ security research will team UCSD Computer Science and Engineering faculty, SDSC’s Pacific Institute for Computer Security, and industrial partners Ericsson, IBM, Orincon, and Qualcomm.

Scalability of software at all levels is critical because Cal-(IT)$^2$ systems will need to accommodate growth to thousands, even millions of devices when production systems are introduced. Software integration alone will not meet these challenges. Many current software solutions for distributed and parallel computing do not scale and cannot be used in the dynamic application environment we envision, requiring us identify new software concepts.

Our “living laboratories” will face a major challenge to enable rapid, secure deployment of experimental software and hardware and rapid recovery from unwanted effects. We will address these challenges by using a software engineering methodology that supports careful design, prototyping, and simulation before deployment. For example, we will use UCSD’s SensorNetSim, a simulator for large-scale sensor arrays, such as used in several application layers. SensorNetSim will provide a framework to implement prototypes of the various software components and a platform to perform “virtual” experiments with sensor arrays prior to deployment of Cal-(IT)$^2$’s sensor infrastructure. In addition, in UCSD’s MicroGrid, we will develop simulations of large-scale computational environments to represent element behavior, interactions, and the impact of load and external factors. Simulation and modeling must occur before deployment to evaluate software/hardware deployment alternatives and
continuously afterwards to understand the behavior and drive the management of Cal-(IT)²’s large-scale, complex, dynamic systems.

The “Grid” is a term that refers to an integrated networked world of computing, sensors, storage, and software. To be effective, it must address a large number of software issues: security; messaging; resiliency to failure and partitioning; authentication of users, code, and data; and utilization. To achieve these goals, we will build on mature research at UCSD and UCI to develop innovative middleware to support scalable programming paradigms and adaptive Grid applications. This work will use distributed “metacomputing” techniques to adapt to dynamic environments. Our research on mobile Grids will benefit by our industrial partnership with Sun Microsystems (collaborating on our extensive use of Java, Jini, Jiro, and Solaris) and IBM.

To integrate wireless “appliances” and other devices with the Internet and support quality of service for multimedia applications, we will focus on mobile agent technology, such as UCSD’s MobiMedia, which enables transmission of appliance-specific “mobile” code to information servers to tailor information at its source to meet a client’s needs before transfer. For instance, a medical image might be filtered for optimal viewing on a portable digital assistant and reduced in size for more efficient wireless transfer. In collaboration with USC’s Information Sciences Institute (ISI), we will add features to the Globus Toolkit to support mobile Grids. Finally, the Cal-(IT)² Grid Portal Toolkit (built on SDSC’s GridPort) will provide an Internet portal testbed to facilitate experiments with wireless, Grid, and metacomputing services.

The imminence of “third-generation” wireless Internet devices will cause a major increase in demand for Grid computing. Users will demand seamless performance as they move from desktop PCs to mobile information appliances. Such performance can only be maintained if computing power and data resources become highly distributed “inside the Internet,” enabling effective distributed data preprocessing, filtering, and data mining. We will work with industrial partners Akamai, Entropia, IBM, Leap Wireless, MedExpert, NCR, SBC, and Sun Microsystems to apply these new techniques to important types of information: scientific databases, commercial databases, and very large text databases. For instance, Webclopedia, a research project at partner USC/ISI, is one example of extending Internet-accessible information to include billions of Web pages available now only as disjoint fragments of natural language. Webclopedia functions by converting the existing “Web of pages” into a “Web of knowledge” that functions as a multilingual encyclopedia to answer simple questions.

Finally, Cal-(IT)² will conduct research on the human-computer interface. We will create large screen “control rooms” for analysis of very large datasets, beginning with California oil and gas companies using immersive visualization. Because of their dense data sets, they are using stereoscopic three-dimensional seismic imaging on 28’ x 8’ screens; this work has clear applicability to our research on telemedicine, disaster response, entertainment, and distributed learning. This work will team our New Media Arts layer, SDSC visualization experts, a research geologist at San Diego State University working with Chevron, and our industrial partner Panoram Technologies.

We will link multiple control rooms so that groups can engage in “virtual huddles,” sharing cyber/physical resources to make sense of complex events, such as earthquake emergencies, fires, floods, and oil spills. The underlying research will be relevant to practical applications, including “smart offices” that will facilitate interaction among Cal-(IT)² participants before the proposed buildings are built. Such an environment will enable users to capture meeting information, summarize it, annotate it, edit it, and re-create it. Ultimately, users will be able to recover the “state” of a situation, in effect like retrieving a saved file from a hard drive, so that subsequent meetings literally can pick up where they left off.

This shared workspace will enable a number of paradigmatic shifts: Time shift, where people will be able to join a meeting that has already taken place, provide their input, and affect the outcome after the fact; space shift where people will be able simultaneously to occupy the same virtual space with
relevant ambience and resources (paper, communication devices, etc.); and environment shift where people will be able to share, swap, or invent an ambience supportive of a discussion they want to have. Shared virtual spaces are an example of adaptive (context-aware) computing, in which the physical and virtual worlds become merged. Once all objects in our workspace know the identity and location of all other objects, it will become possible to use any physical object, gesture, or voice as input devices to the Internet. We will also develop new interface paradigms to target adaptive and context-aware programs to small info appliances.

4. Strategic Applications

Here, we describe Cal-(IT)²’s four strategically chosen applications—Environment and Civil Infrastructure; Intelligent Transportation; Digitally Enabled Genomic Medicine; and the New Media Arts—that will work with the technology layers and the Policy and Socioeconomic Evolution layer (described below). Technology cannot be developed and evaluated in a vacuum. Rather, optimal development choices must be made in a “real world” testbed context. Furthermore, the use of new Internet technologies in the four applications will enable innovative basic scientific and artistic research not possible before. Finally, these applications are all critical to California’s economy and its quality of life.

Environment and Civil Infrastructure. Our ability to conduct detailed studies of our environment and civil infrastructure will be transformed radically by developing and deploying sensor networks supported by a wireless infrastructure, producing—for the first time—a continuously updated set of “state variables” from the field. This, in turn, will enable us to better detect and forecast climate variability, manage natural resources, preserve and restore ecosystems, and carry out crisis management. The challenge is that we must place sensors in remote locations not convenient for landline or commercial wireless access.

As a pilot project, led by the UCSD’s Scripps Institution of Oceanography (SIO), we will define and deploy, over the next four years, what we term the Southern California Wireless Environmental Sensor Network and Information System [WESNIS], extending from the Sierra mountain range on the east to the outer limits of the southern California continental shelf on the west. With the recent offer to SIO from industrial partner Chevron to use three retired offshore oil platforms in central California, we will be able to extend the line-of-sight communications offshore considerably. The data streams from these widely distributed sensors will be integrated in real time with historical data archives and sophisticated computational models of environmental processes in prototype distributed computing, visualization, and information systems (“control rooms”). We have laid a foundation for these rooms with two Keck Foundation-funded “satellite” sites of SDSC and are working with the UCSD Telemedicine satellite, SIO, SDSC, SDSU, and industrial partners Chevron and Panoram Technologies to develop unprecedented capabilities in California to analyze and enable decision making for basic research, crisis management, and industrial exploration of enormous data sets.

We will build WESNIS on previous SIO/SDSC infrastructure using point-to-point wireless Internet links and on a recent NSF award to develop a prototype wireless research/education network in southern California (App. D). In collaboration with these pioneering efforts, we will develop a testbed to provide Internet access to collect and process data from remote field sites across a variety of disciplinary areas. This project will produce a prototype architecture that can be replicated in other regions, across a variety of scales. We will use this information infrastructure to enable two environmental application projects in southern California, described next.

California’s infrastructure of constructed facilities (pipelines, bridges, ports/harbors, offshore structures) is aging. Pipeline failures have already occurred in the Mojave Desert resulting in dangerous explosions and large craters that must be repaired. The same water pipeline system extends
through heavily populated urban areas, often in close proximity to schools, increasing the danger.
Similarly, more than 40% of existing bridge structures are functionally deficient or obsolete and in
need of replacement. Therefore, monitoring the health of this infrastructure and enabling its strategic
renewal (by retrofitting or replacement) is critical not only to extending the infrastructure’s life span by
10-20 years, but by saving California’s citizens the corresponding multi-billion dollar annualized
taxpayer investment. Because of the importance of renewal engineering to the state, UCSD has started
a research and degree program in renewal engineering.

The civil infrastructure can be damaged greatly by earthquakes. The California Division of Mines
and Geology has estimated the seismic risk in California costs more than $4 billion annually.
Following an earthquake, it is vital to assess the integrity of the civil infrastructure immediately.
Currently, such assessment is done via on-site inspection—both time-consuming and insufficient to
quantify the stresses experienced by structures. In this context, UCSD’s Powell Structural Research
Laboratories, the largest lab in the world conducting full-scale controlled testing of buildings, wood-
frame houses, and piers, proposes to prototype with Cal-(IT)$^2$ smart infrastructure management to
monitor infrastructural health and integrity and enable remote monitoring and assessment.

Preparing for earthquake-related emergencies requires continuous acquisition and telemetry of
seismic and geodetic information from ground sensors, synthetic aperture radar and GPS data from
space, and data from sensors monitoring the integrity of the civil infrastructure. Southern California’s
network of broadband seismographs and precision GPS receivers, capable of mm-level accuracy, will
be integrated into WESNIS to provide reliable real-time access to their data. Together with
interferometric synthetic aperture radar data, these sensors will provide a revolutionary synoptic view
of ground displacement in southern California useful for quick response to large earthquakes and
improved earthquake forecasting. Furthermore, adaptive actuators are beginning to be developed that,
for example, can counteract—in real time—the stresses on civil infrastructure, in effect negating the
forces of an earthquake. Such sensors and actuators, as they become available, will be deployed in
WESNIS. Cal-(IT)$^2$ will collaborate with USC’s Information Sciences Institute and Civil Engineering
Department to leverage and build on the collaborative infrastructure for earthquake experimentation,
simulation and analysis being designed and deployed under the NSF-funded National Earthquake
Engineering and Simulation project.

Our second major focus area, the management of the California coastal ocean hydrological system
requires improved technologies to monitor, understand, and predict water resource characteristics, and
water hazards. The California Applications Program at SIO is partnering with the California
Department of Water Resources and the U.S. Geological Survey, which have developed quantitative,
model-based approaches to decision making. We will team to deploy additional low-cost
meteorological and hydrological sensors and link them to WESNIS to collect watershed data to
provide a real-time view of California’s watersheds.

The coastal ecosystem is subject to ever-increasing demands by fishing, commercial shipping,
recreation, and human habitat. Beach closings caused by contaminated runoff is a growing economic
and quality-of-life concern in California. To manage this important California resource, we will add in
situ coastal ocean sensors including biosensors to WESNIS. The real-time data thus captured will be
coupled with sophisticated computational models of associated physical, chemical, and biological
processes. Initially, coastal data incorporated into the wireless backbone will come from an offshore
network of wave-monitoring sensors maintained by the Coastal Data Information Program at SIO. In
addition, we will assimilate real-time coastal ocean data into computational models and make available
estimates of regional coastal currents to applications including emergency response to oil and sewage
spills, understanding pollution disbursement from point sources, and predicting sediment transport
along the coast.

Cal-(IT)$^2$ and SIO will actively collaborate with the privately funded Monterey Bay Aquarium
Research Institute (MBARI) to extend SoCal WESNIS from the San Diego Bay to the Monterey Bay
and from the near-shore coastal waters to the mid and deep ocean. MBARI’s active ocean observatory development program provides a natural complement to the Cal-(IT)² effort, extending the reach of the wireless communication system to both fixed instruments deployed on the seafloor, and autonomous underwater vehicles roaming the coastal ocean. DNA probe-based sensors created at MBARI are allowing the in situ detection of toxic algae for the first time, providing the base technology which will be applied to a range of biological detection problems, including those important in beach pollution. As ocean sensor networks will necessarily operate beyond line-of-sight of land, MBARI will work with our Institute on architecting the wireless sensornet to include "over-the-horizon" sensors that may require satellite links.

**Intelligent Transportation.** In California each year, 24 million vehicles travel 155 billion vehicle miles over 166,000 miles of streets and highways. Even with this intense demand, urban freeways and arteries are managed based on only the coarsest of information (sparsely distributed inductance loop detectors buried in traffic lanes transmit bits of data indicating the presence of a vehicle over wireline to a traffic control center). As a result, traffic congestion is fast becoming one of the principle blocks to California’s economic development. However, the emergence of digital, broadband, wireless communication systems, and advanced information technologies, promises to lay the foundation for a wireless information “central nervous system” for urban transportation that can improve, qualitatively, the worsening transportation crises.

Imagine California in the year 2010. Roadside data stations will broadcast traffic data to passing vehicles while simultaneously collecting detailed traffic flow data. Navigation devices will also have access to commercial navigation and route guidance services that provide augmented traffic data based on advanced traffic prediction algorithms. Vehicle-to-vehicle communication will provide drivers with enhanced local navigation assistance and enable sharing of traffic and other data, fusing dynamic context-aware data with on-board static datasets. We call this concept AUTONET. An autonomous, self-organizing information/control system to manage interactions among “intelligent” vehicles, roadways, and stations.

This vision is realizable. Wireless technology enables a traffic probe vehicle equipped with a Global Positioning Systems (GPS) antenna and a wireless data modem to collect traffic flow data. Private firms, including our industry partners, are deploying in-vehicle devices that will couple map displays with GPS data. As wireless bandwidth increases, so will the ability for private industry to augment the dashboard maps with routing advice. Cal-(IT)², led by the UCI Institute of Transportation Studies and collaborating with UCSD’s Computer Vision and Robotics Laboratory, will create testbeds (Sec. D3) in which public data will be augmented in-vehicle devices equipped with inexpensive, local-area communicators, namely, a second-generation Bluetooth technology. Such communicators will “talk” with the probe vehicle infrastructure, gathering traffic data and sending back flow information. By coupling the vehicles’ processors, each vehicle will contribute local information and a small amount of computing power. In aggregate, the vehicles will form a real-time, distributed database “traffic computer” aware of unpredictable movements of its own individual nodes.

The technical challenges cut across virtually every layer of Cal-(IT)². Bluetooth and existing cellular infrastructure are two extreme architectures, both with deficiencies for transportation-related communication needs. As a result, we need to develop a new kind of distributed architecture with unique protocols, and wireless and wireline infrastructure. For near-term trials, this infrastructure will be based on wireline, high-bandwidth networks running along the sides of roadways, linked to communication and navigation being developed by our industrial partner Qualcomm in collaboration with Ford. We will augment this system with enhanced Bluetooth-like, inter-vehicular wireless protocols.

Specific devices for traffic applications include self-powered, wireless sensors with short-range telemetry; robust sensors with compact, non-volatile memory; and vastly improved position-sensitive
devices. For example, current differential GPS allows positioning of vehicles only within a few meters—insufficient to trace detailed movements of vehicles across lanes of traffic—monitor their acceleration profiles to estimate emissions or reconstruct conditions leading to accidents. Through Cal-(IT)^2 discussions, this application discovered researchers studying earth motion at SIO’s Orbit and Permanent Array Center and the California Spatial Reference Center that have developed GPS positioning algorithms achieving two-centimeter accuracy multiple times a second. We are excited about the potential for transferring these GPS algorithms from seismic activity to AUTONET to obtain accurate real-time positions of vehicles without expensive base reference stations required every 15-20 kilometers.

This application team will work with other layers on data structures and distributed computing in a self-organizing traffic system to develop protocols for a constantly evolving network of moving, in-vehicle processors and develop alternative architectures for the system. We are particularly interested in two-way interaction of passive, multi-modal sensor clusters embedded in the transportation infrastructure with in-vehicle, mobile sensors populating the AUTONET database. We will also develop a distributed, intelligent management and control environment with intelligent consoles and stations for on-demand, semantics-driven, multi-resolution, and multi-perspective viewing of the traffic state, grounded in visualization tools to visualize, navigate through, and interact with the traffic network in real time.

Digitally Enabled Genomic Medicine. Over the past decade, technology created in academia and its transfer to industry sustained strong industrial growth related to drug discovery and telecommunications in the San Diego-Irvine corridor. Through partnerships with industry, Cal-(IT)^2, in turn, will serve as the nucleus for next-generation companies, helping the state assume a leadership role in revolutionizing health care. Recent extraordinary accomplishments in the biomedical sciences, including completing sequencing of human DNA, highlight the complexity of living systems and the challenges for delivering on the promise of genome science to improve health. The combination of personalized (genomic) medicine and the application of wireless technology to health care delivery (digitally enabled medicine) will provide enormous benefit to the citizens of California, the state’s economy, and our society in general.

Our vision is one in which health care professionals and biomedical scientists should be able to gain access to every known fact instantly, regardless of where the information resides or the seeker is located. Clinical practice will require time-urgent, secure delivery of large amounts of patient information. High-speed, high-bandwidth wireless communication devices linked to powerful, interoperable clinical and biomedical databases will empower physicians, extend delivery of genomic medicine to remote clinical settings, increase certainty in diagnosis, and improve effectiveness in clinical practice while reducing costs.

Decisions crucial for urgent medical care (e.g., cardiac monitoring) will be made with information updated on demand, including physiological data from noninvasive biosensors linked to wireless transceivers. Such sensors will lead to digitally monitored smart home care, which will reduce medical costs, minimize hospital stays, reduce the risks and costs of noncompliance, and increase patient awareness to monitoring their own health care. UCI is building an instrumented “smart house” in which some of these concepts can be tested out.

We will build on advances in telecommunications and information technology from the technology layers strengthened by UCSD and UCI leadership in the biomedical sciences. Doing so will require cutting-edge research testbeds on two complementary fronts: telesciences and bioinformatics. Telesciences, pioneered at UCSD, enables scientists to manipulate remote instruments located even continents away, compute models, and steer data collection. This project helped demonstrate (trans-Pacific) IPv6 technology. Working with medical imaging groups at UCSD, LANL, and the New Mexico Brain Imaging Institute, UCSD is now implementing wireless technology to provide the
interactive (information on demand) environment for interdisciplinary teams to establish noninvasive imaging technology, including medically relevant imaging modalities (fMRI and MEG). Building, for example, on the recently announced Israeli “video pill” for continuous monitoring, telescience will permit remote clinical monitoring of patients who then will have the opportunity, perhaps for the first time, to lead normal lives. We will expand the types of clinical instruments enabled by telemedicine technologies through collaboration with our industrial partners Merck and R.W.Johnson Pharmaceutical Research Institute.

New strategies in informatics are needed to discover the meaning and implications of genomic complexity, ranging from uncovering the information implicit in the sequence of the human genome to characterizing the processes involved in human health and disease. This science, bioinformatics, is the backbone of the biotechnology and pharmaceutical industries, a strength of UCSD and UCI, and a research area benefiting from collaborations with local pharmaceutical firms, our information technology industrial partners (IBM, Sun Microsystems, and SAIC), SDSC, the Keck Graduate Institute, and the Institute for Quantitative Systems Analysis in Biology. Research also will also be carried out by our academic team in medical, neural, chemical, and pharmaceutical informatics, in collaboration with our industrial partners Merck, R.W.Johnson Pharmaceutical Research Institute, and Silicon Valley startup MedExpert.

Establishing the connection between the genome and human physiology will entail a quantitative, whole-systems approach to model the integrated activity of tens of thousands of genes. Our biologists will work with the Cal-(IT)$^2$ data-mining team on these challenges, as well as demanding an unprecedented amounts of computing. For example, a recent UCSD/SDSC study concluded that a rigorous (Smith-Waterman) comparison of whole eukaryotic genomes requires a distributed computing approach (similar to SETI@home). Cal-(IT)$^2$ will evaluate industrial partner Entropia’s software for this task.

Our biomedical researchers must work with the Cal-(IT)$^2$ technology layers to gain access to the components critical for digitally enabled genomic medicine. For instance, we need research on non-volatile memory; ultra-high-density storage devices for reliable, sustained repositories; ubiquitous access to high-bandwidth, high-throughput distribution and storage networks; biomedical sensors with telemetry for monitoring and diagnosis by noninvasive imaging methods; miniaturized, microfluidic clinical devices; computational infrastructure to support informatics; data compression and encryption methods; handheld “smart systems” for high-speed retrieval from large volumes of molecules-to-physiology multi-scale data; infrastructure to organize such complex data; and on-demand access for data-intensive computation.

By teaming pioneering researchers across computer science, biology, and materials, we plan to create innovative “living laboratories” for such technology in clinical settings at the UCSD School of Medicine, in public health settings with San Diego County Health and Human Services Agency, and in collaboration with our industrial partners Merck, R.W. Johnson Pharmaceutical Research Institute, MedExpert, and SAIC.

**New Media Arts.** This team will focus on computer games and novel visualization environments to provide creative research challenges likely to have impact on distance learning, collaborative work environments, and understanding large complex data sets. We have chosen computer games because they combine many key elements of the digital media arts--its temporal structures are driven interactively; it has a social dimension; and it has varying degrees of sensory immersion and integration with the physical environment. Computer games are also one of our fastest growing export industries: More than $6.1 billion in U.S. entertainment software sales in 1999 was attributed to games—its fourth consecutive year of double-digit growth. One year previous, more than one in four American youngsters reported playing games 7-30 hours a week. Games also represent a useful paradigm to address design challenges to prototype a new pedagogic form, particularly as it scales up
to very large numbers of users engaging multiple information streams. As a result, we need to evaluate how to adapt its metaphors, design principles, and technologies to other forms of content and delivery. In this context, we will work with the technology layers to:

- Develop wireless input/output devices to coordinate monitoring of virtual presence in mediated realms using micro-/nano-sensors and infrared imaging technology.
- Design interactive media installations and events that demonstrate the capabilities of a hybrid wireless/optical, ubiquitous computing environment. Create innovative audio/visual interfaces to mixed-mode, online educational gaming environments delivered via high-resolution and sensory-immersed displays linked to lower-bandwidth, wireless devices.
- Program mobile agents to explore agency and personification relative to information discovery, delivery, visualization, and navigation and produce non-linear interactive narrative forms including the interpretation and expression of motion and emotion.

Hardware and software development in digital imaging and sound, and their impact on gaming, promise to have a profound effect on the future of cinematic production and delivery—a critical component of California’s entertainment industry. This layer will team with visualization experts from SDSC, UCI, industrial partner Panoram Technologies, and UCSD’s Center for Research in Computing and the Arts (CRCA) to conduct visualization research on how best to express the complexity of wireless data inputs with multiple participants. Panoram Technologies, a Sun Valley California company that has installed 60 facilities worldwide in energy companies, will work with the Cal-(IT)^2 building architects to design cutting-edge visualization facilities, “unique in California” [see letter from Panoram’s CEO, Appendix B]. We will build scalable data visualization environments that include:

- Room-sized visualizations using multiple visual planes and spatialized audio for audiences ranging from dozens to hundreds of people as well as stereoscopic 3-D images to create the effect as if one were viewing the real performance or event in person.
- Wall-sized visualizations that involve multiple users incorporating spatially directed imaging, surround sound, and robust haptic interactivity.
- Portable visualization for networked individual users, including handheld, head-mounted, and biologically embedded devices.

To accomplish this, we will continue developing the underlying specifications for key media components (expressive 3-D graphics, spatialized audio, and semantic media compression) and image storage, presentation, distribution, and manipulation from non-volatile magnetic RAM and 3-D optical storage devices.

Broadening the impact of the proposed activities will be the UC Digital Arts Research Network (UC DARNet), a Multi-campus Research Unit representing six UC campuses; the UC Institute for Research in the Arts (UC IRA); the IDEA Institute (Interdisciplinary Digital Exploration of the Arts); the UCI Interdisciplinary Gaming Studies Program; UCSD’s Sixth College (E, Education), and UCSD’s Interdisciplinary Computing in the Arts Major (ICAM).

5. Policy, Management, and Socioeconomic Evolution

A key part of the institute’s research agenda will be to study how policy and management drive the Internet’s evolution and how the new Internet will evolve society’s institutions. UCI’s Graduate School of Management (GSM), in collaboration with UCI’s NSF Center for Research in Information, Technology, and Organizations (CRITO) and UCSD’s International Relations and Pacific Studies (IR/PS) graduate school will explore how the new Internet alters the management of networked enterprise: Emergence of new organizational forms and transactional systems based on new technologies, implications of these technologies for improving the way business can be conducted, and, the value-creation process by which these technologies are brought to society. This research will
focus in three areas: 1) We will examine the economic, managerial, and strategic impacts of information technology for management, including evolution of the network-based economy, analysis of the impact on organization and market structures, productivity in the new economy, the nature of competition in a global digital economy, and e-business strategy and practice; 2) we will research the changes induced by broadband access to the home and ubiquitous mobile wireless access on the economic and social fabric (households, consumers, and citizens); 3) we will study the challenges facing policy makers in charge of macro-institutional environments and infrastructures in balancing privacy and access, as well as greatly increased interaction with a net-active set of constituents.

Finally, we will build on UCSD’s and UCI’s complementary strengths in policy research to establish strong program in international telecommunications policies on questions related to the evolution and use of wireless networks:

Technical standards and intellectual property: Patent pools and standards setting pose critical commercial challenges to competition policy. Standards setting, especially in Asia, is tied to national industrial policies more concerned with obtaining favorable terms for intellectual property rights on information technology than promoting competition and lower prices. UCSD, together with UC Irvine’s GSM, will study how the process differs across countries with regard to representation, transparency, voting rules, and obligations for licensing intellectual property; and what reforms to suggest.

Promoting universal service: We will analyze technology options to determine how governments could redefine universal service and the most efficient funding mechanism for universal service. An initial study on how wireless infrastructure in rural Mexico could reverse migration from mega-cities will include participation from three UCSD institutions: the Center for U.S.-Mexico Studies, the Center for Comparative Immigration Policy, and the Institute of the Americas, which already has a telecommunications infrastructure project for South America.

Privacy and information security: The battle between the European Union and the U.S. is avoiding many deep issues related to privacy and technological/network development. We will study prevailing privacy principles by collaborating with the Transportation and Environment Assessment application teams. We are already investigating international security and privacy as part of the “Economy project,” a joint effort of the Berkeley Roundtable on the International Economy (BRIE) at UC Berkeley, UC Davis, and IGCC.

Spectrum and competition policies: Plans for allocating spectrum diverge around the world, and many countries (including the U.S.) are not releasing enough new spectrum for advanced wireless networks. UCSD, known for its work on political institutional design, bargaining theory, and auction theory, will work with the technology layers to generate examples of imaginative spectrum planning, suggesting ways to redesign the global system for spectrum allocation and assignment. Initially, the Institute for Global Conflict and Cooperation (IGCC), a multi-campus research unit headquartered at UCSD, will design new tools to support spectrum allocation decisions, and we will assess the feasibility of dynamic allocation of spectrum.

Summary

The intricate interactions between applications and new Internet technologies can only be understood by deploying prototype instrumented “smart environment” testbeds, which will enable institute participants to “live in the future.” The Cal-(IT)$^2$ approach will fill a critical gap in technology transfer because researchers who focus on a particular subcomponent often make unrealistic, simplifying assumptions about the nature of other subsystems, which, in turn, makes it difficult to assess the relative value of individual innovations in a complete end-to-end system. No university or company alone could build such an integrated environment. It is only through the opportunity of the Governor’s initiative that we can pull the unprecedented resources together from multiple campuses.
(including Caltech, Stanford, and USC), industries, and government laboratories to undertake such an ambitious and visionary project and yet have such confidence in the success of the undertaking. UCSD and UCI have taken the Governor’s challenge seriously. We have recruited experienced senior management to create our vision, catalyze our academic teams, develop relationships with committed industrial partners, and write this proposal. We have already raised the needed 2:1 match and anticipate exceeding it considerably. And we have selected the architectural firms, determined our buildings’ technical requirements, and selected conceptual designs (see cover). Our proposal is visionary and time-urgent for the California economy, and we stand ready to turn our vision into reality.

**Timeline and Milestones**

The foundation of proposed Cal-(IT)$^2$ research is underway, and we will build on it aggressively if selected. We have prioritized proposed projects and will also use UC, industrial, federal, foundation, and individual donor matching funds to support the growth of the research staff and capital. The excitement our initiative has generated, with more than 200 faculty members supporting this effort, gives us confidence that we will be even more successful than we appreciate now. Here, we give examples of our plans for the first few years.

To jump start activities across the institute, in Year 1 we will deploy initial infrastructure testbeds building on the foundation of ongoing research activities, recently awarded relevant grants (Appendix D), the two SDSC Keck “satellites,” and continuing UCSD/UCI campus wireless deployment. We will add more sensors to the recently NSF-funded wireless infrastructure supporting seismic and astronomical observations, expand the sites coupled by wireless into the campus testbeds, begin detailed planning of the Sixth College wireless infrastructure (Sec.E), build a data analysis and visualization “control room” at SIO, extend the bioinformatics data-mining infrastructure through the “Alliance for Cell Signaling” and “Joint Center for Structural Genomics” grants (which includes the Stanford Synchrotron Radiation Laboratory), and, to ensure effective ongoing communication, implement multi-site videoteleconferencing among SDSC, SIO, the Jacobs School of Engineering, and UCI.

Given the limitations of space in the RFP, we illustrate our approach by considering plans for two layers and one applications area, each of which is representative of our plans overall for the institute. For Materials and Devices, in Year 1, we will develop prototypes of self-powered wireless sensors for nanophotonic optical filters and stress/motion position sensors, and establish device and system requirements for efficient optical networking. In Year 2, we will make new devices for high-speed networks, including practical GaAs MOSFET for “Fourth Generation (G4) handsets, all-optical wavelength converters, molecular ultra-fast optical switches, and high-performance G4 GaN telecom devices. In Year 3, we will produce prototype devices: LED/LD on silicon, implantable biosensors, silicon magnetoresistive nanowires, near-field optical switch devices, and cuprate superconducting filters. In Year 4, we will complete development of devices for several institute applications: polymer interconnects; 10-micron blood-born pressure sensors; wireless *E. coli* water pollution sensors; and 3-D DNA array detectors.

The Interfaces and Software Systems layer will design and implement software to integrate information and knowledge management systems with wireless access protocols, visualize large, sensor-gathered data sets, and support data subsetting for handheld devices; integrate software developed in various projects (e.g., SensorSim, MobiMedia, and Grid Portal Toolkit) to create a more capable, easier-to-use infrastructure overall; work with computational scientists to develop new applications which utilize tens of thousands of Entropia processors.

Similarly, the Environment and Civil Infrastructure team will build on an existing wireless network in San Diego, Riverside, and Imperial counties to deploy broader coverage nodes in Orange County, the coast region, and from offshore platforms, integrate access to real-time data and distributed
archives, visualize large-scale multidimensional, heterogeneous data, and prototype a first-generation
digital “field tool.” Then we will build out wireless coverage to include Santa Barbara Channel and the
lower Sierra Nevadas, integrate access to archives, computations, and collaborative decision making
among multiple “control rooms,” and roll out more general information portals for educators and
policymakers.

II. Relevance
Cal-(IT)$^2$ will extend the power of the Internet in applications critical to the vitality of California’s
economy and new users, applications, and industries will emerge as a result of the infrastructure we
create. To illustrate our plans we describe below specific plans for innovation in the areas of
Environment and Civil Infrastructure, Intelligent Transportation, Networking and Computing in
partnership with Qualcomm, Ericsson, Leap Wireless, GlobalPhoton, TeraBurst, IBM, SiliconWave,
Sun, Entropia, Lucent, CALTRANS, USC/ISI, LLNL, and SDSC. Our approach to fostering this is via
the deployment of testbeds, that use the core technologies described in section D1.

**Environment and Civil Infrastructure** Cal-(IT)$^2$ will partner with the UCSD Powell Structural
Research Laboratories, which is the largest lab in the world conducting full-scale controlled testing of
buildings, wood-frame houses, and piers. Testing of large models demonstrates the need for wireless
sensors: A recent test of a wood-frame house with more than 300 instruments required three miles of
cable! The experiments’ data transmission and teleparticipation requirements also call for state-of-the-
art networking, data management, and visualization technologies, which Cal-(IT)$^2$ will supply. These
efforts will enhance and accelerate structural integrity and safety of California’s public and private
structures. Going the next step, routine, real-time monitoring to assess the structural integrity of civil
infrastructure will involve instrumenting hundreds of CalTrans bridges over the next 10 years. UCSD
and CalTrans are developing a comprehensive bridge health-monitoring program starting with several
bridges across California; UCI has instrumented two bridges in Orange County. Cal-(IT)$^2$ will
collaborate on instrumenting these bridges as prototype “smart civil infrastructures.” Two bridges
under construction near the Salton Sea will be equipped with sensors as a wireless extension of
WESNIS. This is a precursor to the high-visibility, cable-stayed, composite bridge planned across
Interstate 5 linking the east and west sections of UCSD’s campus. The point here is that civil
infrastructure management will depend on sensor data on a large scale, with the best decisions based
on overall system performance rather than localized data in isolation. Through these testbeds, Cal-(IT)$^2$
will create the proven system that must predate any large scale commercialization or full scale
deployment on California’s 24,000 bridges.

**Intelligent Transportation** will upgrade the UCI Institute of Transportation Studies’ testbed of
high-speed fiber communications links to the local Caltrans District in Orange County. The university
laboratories associated with the testbed have access to network-wide traffic surveillance and control
information in a real-time environment, which provides the ability to issue a closed-loop response to
the traffic conditions through remote control access to field elements such as ramp meters and traffic
signals. UCSD’s Computer Vision and Robotics Laboratory will use real-time machine vision systems,
remotely controllable platforms and devices, and mobile systems to collect sensory information to
support the proposed experimental, systems-oriented research. Our efforts in this regard will provide
proof of concept for new commercial transportation applications.

**Networking.** The UCSD Cal-(IT)$^2$ building, one of the tallest structures on campus, will include
a roof top wireless networks laboratory with provisions for mounting radio frequency antenna arrays
and free space laser transceivers. This hub will be the launch pad for a network testbed. Leap Wireless has committed to providing access to cellular spectrum in California (fully supported access to one 1.25 MHz cellular channel at 10 cell sites for 10,000 hrs./year involving up to 5,000 subscribers) for studies in remote delivery of content. Global Photon Systems, a pre-IPO company, will provide four-year access to their 800 mile long, environment friendly, undersea, OC-3 (155 Mbits/s), fiber-optic, wide-area network that links seven high tech clusters along the California coast from San Diego to San Francisco. TeraBurst, another pre-IPO partner, will provide early access to state of the art, high speed, optical cross connect systems.

In partnership with Ericsson, Lucent, Qualcomm, and Silicon Wave, UCSD and UCI will expand their existing campus wireless telecommunication infrastructure to cover all departments affiliated with the institute and selected areas of students’ living and work space, creating our first “living laboratory”. We will focus on the interoperability of equipment from different vendors, access architectures, multimedia services (video distribution), and interfacing to ad hoc networks that use Bluetooth, IEEE 802.11, and other RF solutions. Instrumented testbeds will allow us to test and deploy new algorithms, protocols, and designs, such as HDR and Bluetooth, in a real world environment.

An all optical testbed backbone among SDSU, UCSD and UCI will evolve over the lifetime of CALIT2. We envision several wavelengths of an all-DWDM network (Providing multiple 10+ gigabit pipes) to be dynamically provisioned through technology developed by TeraBurst, Inc, a Cal(IT) Partner. A continually evolving optical core is an essential complement to the wireless network. In collaboration with SDSC and the Lawrence Livermore National Laboratory (LLNL), we are engaged with the National Transparent Optical Network, into which we would couple our local optical testbed. We also plan on coupling NTON to the University of Illinois at Chicago, Star Light, the next-generation optical STARTAP, the NSF funded “port of entry” for international research networks.

Computing. In collaboration with Sun Microsystems, we will build an integrated, multi-campus, multiplatform Solaris “metacomputer” testbed which will provide the institute’s primary UNIX compute capacity. Working with SDSC, IBM, Entropia, and other industrial partners, we will build Linux and Windows PC clusters surrounded by a vast Internet PC-based distributed computing service to support highly scalable applications as telecommunication system emulation, bioinformatics, computer graphics rendering, and environmental modeling. In collaboration with SDSC and LLNL, we will explore the commercial feasibility of the experimental IBM Blue Light, a unique extreme computing architecture, involving multiprocessor nodes tightly coupled by a high-speed network. We will develop and deploy very large (10s of terabytes) data warehouses implemented on parallel hardware to support sophisticated data-mining. USC/ISI working with SDSC will install the widely deployed Globus Toolkit on all institute machines, enabling Grid middleware and extend our compute capability to our wireless testbeds. SDSC will provide support personnel to deploy and maintain a distributed software, hardware, and telecomm infrastructure.

Other testbeds will include UCSD’s planned Sixth College and related underserved- and minority-oriented and testbeds (Sec. E) to extend the power of the technology we develop to new communities, evaluate their effectiveness in those contexts, and enable feedback from them to the technology developers.

III. Facilities and Resources

Cal-(IT)² will create leading-edge research laboratories and supporting facilities in two new buildings (Sec. C), with major capital investment in clean room facilities and specialized laboratories. At UCSD, Materials and Devices faculty will establish a facility for epitaxial growth, nanofabrication, and advanced characterization. The facility will include dry etchers to form micro- and nano-
structures; material deposition chambers; optical lithography and, for nanoscale patterning, electron-beam lithography; scanning-probe and near field optical microscopes; a molecular beam epitaxy system integrated under ultra-high-vacuum with a scanning tunneling microscope for atomic-scale investigation of epitaxial growth of quantum semiconductor structures; X-ray photoelectron and Auger electron spectroscopies to determine material composition; a scanning electron microscope with better than 4-nm resolution to study quantum structures; and deep UV microscopes to observe ultra-fine features beyond the limit of conventional optical microscopes.

The corresponding UCI Materials and Devices faculty will house a new molecular/polymer lab for developing molecular sensors embedded in polymer matrices and hybrid bio-polymers for broadband sensors, wave-guides, and high-frequency devices for wireless communications, environmental sensing, proteomics, and bio-chip applications. An expanded Integrated Nanosystems Research Facility (INRF) will enable frontier work on micro-electro-mechanical system (MEMS) devices, high-speed, low-power electronic materials and devices, superconductors, and spintronic structures for the Intelligent Transportation, New Media Arts, and wireless communication applications.

Networked Infrastructure will establish specialized laboratories at UCSD focusing on circuits, systems-on-a-chip, wireless and photonic networks, and magnetic recording. These labs will support research in advanced switching ICs, network processors, gigabit routers, dynamic re-configurable processors, mixed-signal ASICs, and radio-frequency integrated circuits; propagation studies; algorithms and architectures for coding, modulation, and signal processing; and network access protocols in real and hardware-simulated photonic and mobile, wireless communication, and magnetic recording systems. The facility will include microwave probe stations for optical and microwave characterization of opto-electronic components; femtosecond tunable lasers to generate ultra-short optical pulses, a wideband spectrum analyzer, and 10-Gbit-error-rate tester for characterization and performance testing; and phase noise test set and low-phase microwave sources for characterizing phase noise cross-talk levels in close-by communication channels and the Guzik head and media tester machine.

New Media Arts will implement a lab for research related to interfaces and environments for telepresence and experimental interface technologies; a fabrication and scanning lab to develop 3-D environments, research tools, device prototypes, and large-scale equipment and props for digital cinema and computer game environments; an audio spatialization lab for research in multi-channel, real-time audio systems for advanced virtual-reality environments; and a public event performance space. Together with the SDSC Visualization Lab and industrial partner Panoram, New Media Arts will implement a virtual-reality visualization lab, multi-megapixel walls, HDTV, and digital video editing suites and audio recording studios to support complex visualizations and analysis of large data sets. Finally, this team will create, initially in the UCSD Jacobs School of Engineering, a digital gallery to present results of the institute in ways compelling to the public.

To support the research projects, we will put in place a strong in-house professional technical team to develop and maintain institute software infrastructure and the persistent, functional testbeds required for Cal-(IT)$^2$ software and applications research. The technical staff will partner with computer scientists; networking, materials, and applications researchers; and educators and students to deploy Cal-(IT)$^2$ software on a large scale and provide a critical and functional prototype on which Cal-(IT)$^2$ researchers can build.

**Industrial Facilities.** IBM will provide access to its most advanced semiconductor processes, such as 100-GHz Silicon-Germanium for RF and new Internet circuits, as well as advanced 0.13-um CMOS circuits, which will provide a one-of-a-kind resource for California academics to develop state-of-the-art integrated circuits. STMicroelectronics will provide access to advanced technology including their design kits and mask processing.
IV. Education

Wireless Internet capabilities will have a profound impact on the delivery and accessibility of education. Educators must leverage this capability to prepare today’s students who will become tomorrow’s workforce in an environment founded on this technology. Moreover, this revolution in technological capability will allow us to re-invent delivery of education to all California students, regardless of location or income. UCSD and UCI together are slated to accommodate nearly 40% of Tidal Wave II growth anticipated by UC. Since our two campuses are leaders in telecommunications and information technology research and have strong relationships with industry in these areas, we have a unique opportunity to marry the research, commercial, and education thrusts of this proposal and have an impact on an unusually large student population by comparison with other UC campuses.

Technology Development. Cal-(IT)$^2$ will create the Center for Excellence in Educational Technology (CEET) to design and develop information technology specific to the online educator and facilitate adoption of this technology though faculty workshops. CEET will employ a professional interdisciplinary staff of educators, software engineers, graphic designers, and education researchers to design and develop the “Learning Platform,” an easy-to-use, flexible tool that will allow educators to create and publish online courses. These courses will be incorporated into UCSD and UCI degree programs and advertised to our industrial partners.

Research on Technology Efficacy. We must ensure our tools meet the needs of educators and contribute to, rather than hinder, students’ education. Cal-(IT)$^2$ will team with faculty in UCSD’s Communication Department to conduct research studies on the efficacy of teaching and learning using the most advanced telecommunications and information technology, disseminate findings to the community through workshops and seminars, and provide research opportunities for undergraduates, graduates, and industrial fellows. UCI’s Center for Education, partnering with Microsoft, will contribute expertise/software for learning experiments with children and adults. We will also partner with USC/ISI’s Center for Advanced Research in Technology for Education, which develops and evaluates new technologies that promote problem-solving skills.

Technology Assessment Testbeds. The efficacy, scalability, and socio-cultural implications of a new technology, such as the Learning Platform, can be assessed only by testing in the field. Here, Cal-(IT)$^2$ has a unique opportunity: A new college—Sixth College at UCSD with its theme “Art, Culture and Technology”—provides an innovative and exciting opportunity to develop an undergraduate educational institution founded on ubiquitous telecommunications and information technology. Sixth College will pioneer radically new teaching, communication, community, and lifelong learning paradigms, and blur the distinction between “in the classroom” and “in the field” to provide a more comprehensive learning environment. Students will learn about technology, use it in/outside the classroom, and provide feedback to the technology layers about areas requiring additional research/development. Wireless infrastructure will be incorporated into the very design of this college’s infrastructure and curricular planning.

Additional testbeds will address the needs of inner city and rural high schools, the Native American community, and industry. Research demonstrates that the failure of California’s inner city and rural high schools to offer advanced placement courses is a major obstacle to students advancing to the UC system. We will team with UCSD’s Center for Research on Educational Equity and Teaching Excellence (CREATE) to compare the consequences and benefits of distance learning to traditional approaches and with UCSD’s Native American Outreach Program that provides campus resources to prepare K-12 Native American students to become UC-eligible. Furthermore, our industrial partners will provide an excellent additional testbed to evaluate the efficacy of the Learning Platform and other CEET tools.
**Teacher Education.** Research indicates that teachers who use technology *while learning to become teachers* are more likely to infuse technology effectively in their teaching practice. Therefore, CEET will work with teacher education programs at both campuses and SDSU to integrate Cal-(IT)$^2$-developed technologies into their curricula and proselytize their adoption.

**Fellowships.** Cal-(IT)$^2$ has raised more than $12$ million for graduate student fellowships. We will use these funds to attract a pool of talented graduate students and support them for their first two years of study. During these early course-work years, graduate students are typically not ready to conduct research, making it difficult to support them on focused research projects. Cal-(IT)$^2$ principal investigators will support them in subsequent years on relevant research grants.

**Professional Development.** The ability to stay abreast of new knowledge is becoming an increasingly serious problem for professional workers, especially those in industries related to emerging technologies. Numerous telecommunications companies have asked UCSD and UCI to provide employee development. But companies cannot afford to send employees to our campuses, nor do faculty have time to go to them. The solution is time- and location-independent delivery of education, i.e., Internet-based courses. According to Nokia (Appendix B), “One of the most fruitful aspects of our collaboration with UCSD has been in education. The university has been open and responsive to the needs of industry, and has initiated new curricula at the suggestion of [our] Board. Programs initiated through Cal-(IT)$^2$ will help UCSD educate students in the skill sets our companies need.”

A senior-level design capstone course is a part of UCSD’s Electrical and Computer Engineering curriculum. Cal-(IT)$^2$’s Corporate Partners’ Program (CPP, Sec. F) will enhance this program by matching Cal-(IT)$^2$ sponsors with groups of students. Sponsors will serve as technical contacts whom students can interview and request advice to develop design specifications and complete other projects. Cal-(IT)$^2$ will underwrite the costs of the materials for projects in telecommunication and information technologies, and support other UCSD and UCI campus units to incorporate a design requirement or option in their curricula.

**Industrial Participation in Education.** Industry scientists will work in residence at Cal-(IT)$^2$. They will participate in the institute’s day-to-day research activities and mentor graduate and undergraduate students with respect to how theory finds its way into practice. CPP will oversee an internship program to help partners identify and place undergraduate students at company sites for summer employment and in academic internships during the school year.

**Timeline and Milestones**

In Year 1, we will establish the Center for Excellence in Educational Technology, begin developing the Learning Platform, launch the internship program, identify courses most receptive to integration of Cal-(IT)$^2$ technology tools, and design the Sixth College ubiquitous computing infrastructure. In Year 2, we will distribute and support the initial release of the Learning Platform, team with the teacher education programs to integrate Cal-(IT)$^2$ technology tools into their curricula, and begin research studies to evaluate the efficacy of technology use vs. traditional learning approaches in the classroom (leveraging the various testbeds). In Year 3, we will roll out completed courses, admit the entering class at Sixth College, and host class sessions of the teacher education programs in this novel learning environment to they can experience its power in person. In all years, we will recruit and support talented graduate students with fellowship funding.

**V. Industry Participation**
From the beginning, our design of Cal-(IT)$^2$ included a very close tie to industry. As our faculty formulated plans for research based on the abstraction of the integrated layer structure of the new Internet, they worked with campus administrators and the corporate partners developed by UCSD’s Jacobs School of Engineering, SDSC, and UCI’s Samueli School of Engineering to attract key companies in each subcomponent. What has attracted so much enthusiasm from our industrial partners has been our holistic systems approach to the new Internet. As the President of AT&T Labs says in his supporting letter, “Cal-(IT)$^2$ provides a platform for components manufacturers, software innovators, device makers, and telecommunications providers to work together creatively on issues such as availability, quality of service, seamless operations between wired and wireless devices, and policy issues such as privacy.”

We have been flexible in negotiating agreements with industrial partners, recognizing the unique needs and assets of each company. In total, UCSD and UCI have raised more than $139 million in firm industrial commitments (Section C), from 28 industrial partners. Private Donors have contributed another $32M. We also have strong letters of support from another sixteen companies with whom we are still engaged in discussions. Therefore, we expect the industrial cost sharing number to rise considerably over the next six months.

We believe that the very strong response from industry as shown in the size of their financial commitments, verify that our vision, while arguably ambitious, can be achieved. We have completed agreements with a broad set of California “leadership companies,” (Appendix B), such as Akamai, AMCC, Boeing, Broadcom, Conexant, Copper Mountain Networks, Emulex, Ericsson, IBM, Intersil, Irvine Sensors, Johnson & Johnson, Leap Wireless, Merck, Microsoft, NCR, Orincon, Qualcomm, SAIC, SBC, Sun Microsystems, Texas Instruments, and WebEx; but we have also focused on including key small privately held companies such as Caimus, Entropia, Global Photon, MedExpert, Panoram Technologies, Silicon Wave, and TeraBurst Networks.

Besides proposed useful in-kind donations ($56M), the firm cost-sharing contributions from our industrial and foundation partners will support academic professionals ($15M), visiting researchers, student fellowships ($12M), endow 12 new faculty chairs ($14M), provide support for young faculty ($5.6M), establish “named” laboratories, and provide research personnel. This might usefully be compared to the NCSA Industrial Program that the Director previously ran. In the fifteen years of that very successful program, only about $60M were raised, roughly half of what Cal-(IT)$^2$ has raised in nine months.

Every Cal-(IT)$^2$ industry partner will be asked to nominate a senior executive to serve on the Cal-(IT)$^2$ Industry Council. In partnership with Cal-(IT)$^2$ and campus academic leaders, the Cal-(IT)$^2$ Industry Council will help guide our broad strategic vision for the institute. Industry engineers and scientists will be in residence at Cal-(IT)$^2$; they will participate in the day-to-day research activities of the institute and offer graduate and undergraduate students valuable insights by serving as mentors to summer interns. A Senior-level design capstone course is already a part of the ECE curriculum at UCSD. We will enhance this program by matching Cal-(IT)$^2$ sponsors with groups of students. The industrial partners responding to the Governor's initiative have also provided an increase in support to ongoing University-Industry programs. For example, three of the Cal-(IT)$^2$ partner companies (Ericsson, AMCC, IdeaEdge) will be simultaneously joining the Center for Wireless Communications at UCSD, including the CWC annual dues in their pledge to Cal-(IT)$^2$. Conversely, three of the 16 current CWC members (Qualcomm, Intersil and Conexant) partnered with Cal-(IT)$^2$.

An innovative feature of the technology transfer approach of Cal-(IT)$^2$ has been to include venture capital firms in our industrial partners. VC firms ideaEDGE Ventures (focused on creating and launching global companies in the emerging mobile Internet markets), Enterprise Partners, and Mission Ventures will provide counsel on prospects for commercialization of innovations created by Cal-(IT)$^2$, as well as future investments in technologies developed by Cal-(IT)$^2$ if appropriate. As ideaEDGE Managing Partner Rick LeFaivre says in his letter of support: “A key reason for ideaEDGE
Ventures locating in San Diego is the flow of ideas and students from UCSD, which has been instrumental in establishing San Diego as the leading wireless technology center in the United States.”

UCSD has a long tradition of working with industry through its CONNECT program, JSOE, and SDSC that will serve as the foundation for industrial relationships in Cal-(IT)². UCSD will place a full-time member of its Technology Transfer & Intellectual Property Services Office in the Cal-(IT)² building to work with faculty on opportunities regarding licensing, patents, and other intellectual property. UCI’s GSM will leverage the Irvine Innovation Initiative (I³), a pre-incubator to provide students with space and encouragement to turn ideas into businesses.

We are also pleased to be supported by many southern California industrial associations (Appendix C) including BIOCOM (340 member companies), the San Diego Chamber of Commerce, the San Diego Defense & Space Technology Consortium, the San Diego Mayor’s Council for Science & Technology, the San Diego Regional Economic Development Corp., the San Diego Regional Technology Alliance, the San Diego Software and Internet Council (435 members), the San Diego Telecom Council (160 members), the Orange County Business Council, the Building Industry Association of Southern California, UC Irvine’s Chief Executive Roundtable, and the Irvine Company.

Finally, we believe there is a potential for great synergy between Cal-(IT)² and the UC Industry-University Co-operative Research Programs (CoRe), administered through the UC office of the President. The Cal-(IT)² research focus overlaps with elements of MICRO, CoRe, DiMi and SMART. The need to raise additional funds for focused research projects from private industry will greatly benefit from the leveraging of these funds through the IUCRPs.

**Timeline and Milestones**

We have been fortunate that industry has found our vision so compelling that we have adequate funds committed to implement our research plan as laid out in Section D2. Because we have built our program on existing faculty strength, we can work as a virtual institute while our building is being built. We will form the Industry Council in Dec. 2000 if we are selected with the first meeting scheduled for 1st Quarter, 2001. In May, 2001 we will hold our first Science and Technology review, inviting interested members from our industrial partners and our VC partners to scan the presentations for potential ideas for technology transfer. We will fund some students in the Winter quarter, 2001, gradually expanding the numbers in Spring quarter with a summer intern program starting in Summer, 2001. We will aggressively recruit Endowed and junior faculty, funded by industrial funds, starting in Dec. 2000 with the goal of filling a number of the positions in Fall 2001 and all by Fall 2003.

The Director developed a complete evaluation process for success of industrial partners during the previous 15 years at NCSA. This includes quarterly tracking of funded projects, mutual review by faculty and industry of progress toward goals, annual S&T “Fairs” with interactive exhibits of projects, and institute staff to work full time on the management of the industrial program. We expect to blend this approach with the local UC experiences, such as with the industrial programs of UCSD’s CWC and UCI’s INRF.

**VI. Leadership and Management Plan**

The institute will be directed by Dr. Larry Smarr, the founder and 15-year director of the National Center for Supercomputing Applications (SDSC’s sister NSF-supported supercomputer center) and the National Computational Science Alliance (NPACI’s sister partnership). The Alliance links 100 researchers at 50 universities with some 400 faculty, students, and staff at NCSA. Smarr created the Strategic Industrial Partners program at NCSA (which brought in more than $50 million in industrial funding over 15 years) and also was one of the founding scientists in the UIUC Beckman Institute, the largest interdisciplinary center under one roof in the U.S. While Cal-(IT)² shares Beckman’s interdisciplinary vision, it adds an explicit emphasis on core technologies and applications enabled by telecommunication and information technology.
Smarr will report to UCSD Chancellor Robert C. Dynes and be assisted by Chief Scientist Ronald Graham, the UCSD Irwin and Joan Jacobs Professor of Computer Science and Engineering. Previously, Professor Graham was Chief Scientist at AT&T Labs. Dean Robert Conn of the UCSD Jacobs School of Engineering, has had primary institutional responsibility for the development of this proposal. During his tenure, UCSD’s JSOE has risen faster in the *U.S. News and World Report* rankings than any school of engineering in UC history, now standing 7th among public universities. Thus, our institute leaders have experience working on activities of a larger scale than Cal-(IT)², and all with strong industrial partnerships.

Two associate directors, Dr. Ramesh Rao at UCSD and Dr. Peter Rentzepis at UCI, will oversee operations at their respective campuses. Rao is Director of UCSD’s Center for Wireless Communications (CWC), which has 17 industrial sponsors and supports 45 Ph.D. students under the direction of 17 faculty members on communications circuits, signal processing, communications theory and systems, and wireless networks. CWC has attracted $12 million in industrial funding since its founding six years ago. Rentzepis is Presidential Chair and Professor of Chemistry and Electrical and Computer Engineering at UCI. Previously, he was head of chemistry at Bell Labs, has been awarded numerous national and international prizes, and is a member of several U.S. and foreign academies of sciences.

![Figure 4: Cal-(IT)² Organizational Structure](image)

It is noteworthy that Professors Dynes, Graham, and Rentzepis all held senior management positions at Bell Labs, considered by many the most successful industrial laboratory in history. The Presidents of both AT&T Labs and Lucent Bell Labs, have also written strong letters of endorsement and SAIC, the parent company of Bellcore, is a full industrial partner of ours. Thus, Cal-(IT)²’s leadership is well positioned to create an institute capturing the spirit of Bell Labs, with a focus on the telecommunication and information technologies of the 21st century. Smarr, Rao, and Rentzepis will have technical oversight responsibilities for selected layers and applications. Smarr will oversee the Policy, Applications, and Interfaces and Software Systems layer. Rao will oversee the Networked Infrastructure layer. And Rentzepis will oversee the Materials and Devices layer. In each layer, the overseer will have intellectual responsibility for activities at both campuses. At any given interface in Cal-(IT)²’s layer “cake,” the two responsible for either side of the interface will interact to reach decisions. Graham will oversee integration of industry with the academic research and educational activities in all layers. The three directors and Graham will constitute the Office of the Director.

Under Cal-(IT)², UCSD will have lead responsibility overall. UCI will provide leadership in Intelligent Transportation and in Management in a Networked Economy. All technology layers and the four applications thrusts will include complementary science and technology groups at both campuses. Each institute layer and application will be led by two faculty researchers, one from each campus, who will coordinate projects in their respective areas and ensure that integration is achieved intellectually across the campuses. Those from each campus will comprise their campus’ Executive Committee (Table 1), which, together with the Industry Council, will define and guide the institute’s long-term
research agenda. Each Executive Committee, chaired by the respective associate director, will review the research plans and advise the director on how to optimize the institute. Members will serve staggered two-year terms to keep the brain trust fresh while preserving intellectual continuity.

<table>
<thead>
<tr>
<th>Layer or Applications Area</th>
<th>UCSD Executive Committee</th>
<th>UCI Executive Committee</th>
</tr>
</thead>
<tbody>
<tr>
<td>Materials &amp; Devices</td>
<td>Ivan Schuller</td>
<td>G.P. Li</td>
</tr>
<tr>
<td>Networked Infrastructure</td>
<td>Paul Siegel</td>
<td>Magda El Zarki</td>
</tr>
<tr>
<td>Interfaces &amp; Software Systems</td>
<td>Francine Berman</td>
<td>Dan Gajski</td>
</tr>
<tr>
<td>Environment &amp; Civil Infrastructure</td>
<td>William Hodgkiss</td>
<td>Maria Feng</td>
</tr>
<tr>
<td>Intelligent Transportation</td>
<td>Mohan Trivedi</td>
<td>Wilfred Recker</td>
</tr>
<tr>
<td>Digitally Enabled Genomic Medicine</td>
<td>John Wooley</td>
<td>Pierre Baldi</td>
</tr>
<tr>
<td>New Media Arts</td>
<td>Sheldon Brown</td>
<td>Alan Terricciano</td>
</tr>
<tr>
<td>Policy, Management, &amp; Socioeconomic Evolution</td>
<td>Peter Cowhey</td>
<td>Vijay Gurbaxani</td>
</tr>
<tr>
<td>Education</td>
<td>Gabriele Wienhausen</td>
<td>Robert Beck</td>
</tr>
</tbody>
</table>

Table 1: Initial Members of the UCSD and UCI Executive Committees

The two Executive Committees will meet together monthly via video teleconference and quarterly face-to-face, alternating between UCSD and UCI. It is clear that the greatest failure mode for such an enterprise is the possibility that the faculty will fail to cohere in the systematic manner envisioned in the research plan. The Directors together have many decades of experience at the success and failure modes of large research teams, both academic and industrial. We have decentralized the leadership as much as possible, with local autonomy on each campus, and yet by the organization structure ensured a high level of coherence to the vision and its implementation.

To enhance communication across this distributed enterprise, we will use the very high-speed telecommunications infrastructure we will be studying to experiment with videoteleconferencing and collaboration technologies: the Access Grid from Argonne National Laboratory; the Digital Amphitheater and Webclopedia, research projects from partner UCS/ISI; and WebEx, Inc. software. The Access Grid and WebEx are already operational at SDSC.

UCSD has had a Steering Committee, led by Dean Robert Conn, composed of the UCSD principal Deans and Directors, plus the Vice Chancellor for Research, which has ensured that all academic concerns are brought to the senior management of the Institute. This Steering Committee will be joined with a parallel UCI Steering Committee chaired by William Parker, Vice Chancellor of Research and composed of the UCI associate director and the principal deans. The Directors of SIO and SDSC will join this committee.

In addition, we have formed an External Advisory Board (EAB) to guarantee that institute research is of the highest caliber seen from a national and California perspective. The EAB will therefore be co-chaired by senior experts from California and Washington, DC. We have recruited Forest Baskett, a venture partner in New Enterprise Associates, a Bay Area venture capital (VC) firm that just raised the largest VC fund in history. Baskett was a distinguished computer scientist at Stanford University when Sun Microsystems, MIPS, and SGI spun off, and he served for more than 10 years as CTO for SGI. We recruited Phil Smith to serve as co-chair. Smith is one of the most senior science and technology policy experts in the nation, having been Executive Director of the National Research Council for 13 years and having served in every presidential administration since Eisenhower’s.

In addition, the following prominent national figures in institute focus areas have agreed to serve on this board: Karl Hess, Swanlund Chair of Electrical Engineering, UIUC (co-founder of the
Beckman Institute for Advanced Science and Technology, and Co-director of the NSF funded Distributed Center for Advanced Electronics Simulations; Deborah Estrin, UCLA Professor of Computer Science and [Director of the Laboratory for Embedded Collaborative Systems]; Andrew Viterbi, President, The Viterbi Group [Member, President’s Information Technology Advisory Committee]. The co-chairs are currently in discussion with three other nationally prominent researchers to join the Board if the institute is funded.

**Evaluation.** Successful strategies related to accountability and periodic review of progress developed through the two NSF PACI partnerships to manage large, distributed, interdisciplinary teams will be adapted. Institute progress and plans will also be reviewed periodically by the EAB. Industry sponsors will monitor progress via periodic reports and on-site research reviews. In addition, a variety of human resource metrics will be monitored to evaluate success, including the two campuses’ competitiveness for relevant research grants, the ability to achieve greater than 2:1 cost matching, the number of spin-off businesses or amount of technology transfer to industry, the number of students graduated who participated in the institute, the number of participant undergraduate students who continued to graduate school, and the number of publications produced by participating researchers.

**Timeline and Milestones**

At the start of the project, we will prioritize research activities to target initial hiring of academic professionals. We will also hire administrators to support operations (Sec. C). With respect to communication both within the institute and with interested parties outside, in Year 1 we will establish a Web site and tour program; install Access Grid nodes at SIO, UCSD’s Jacobs School of Engineering (JSOE), the Visual Arts department, and at UCI H. Samuei School of Engineering (HSSOE); begin experimenting with VTC tools to integrate activities in the absence of a centralized location; and, in years 2-4, conduct annual institute meetings for all participants. In year 2, we will design and build an exhibit gallery temporarily housed in JSOE. We also expect to report annually to UCOP and additionally as needed on institute progress, new technology trends, and research plans for the future. The executive committees will meet monthly for at least the first year, then move to quarterly meetings, with some members being rotated off and new members rotated on at the start of Year 3. The steering committees will meet quarterly. The EAB will start meeting annually in Year 1, with some rotation of membership in Year 3.