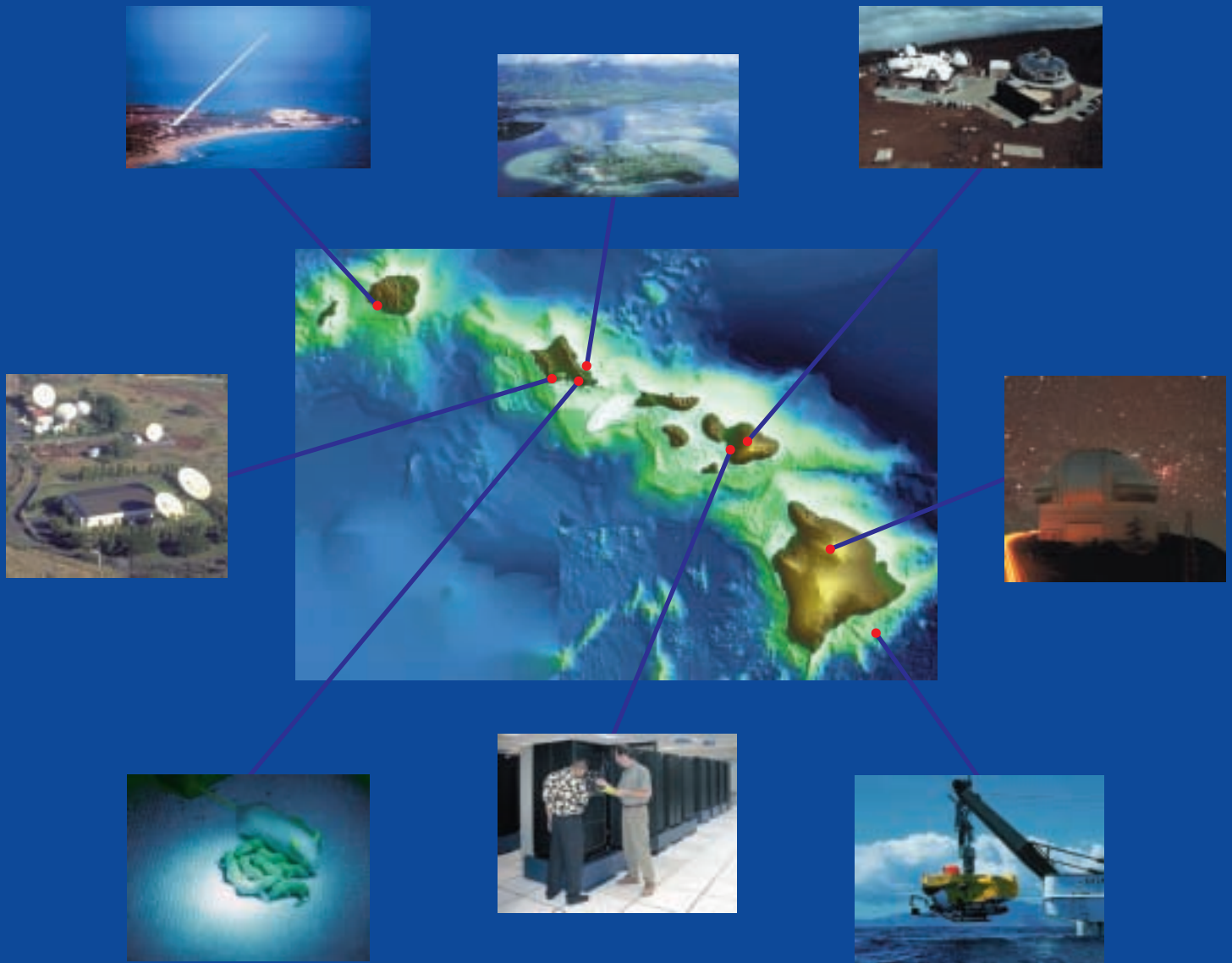


SCIENCE & TECHNOLOGY

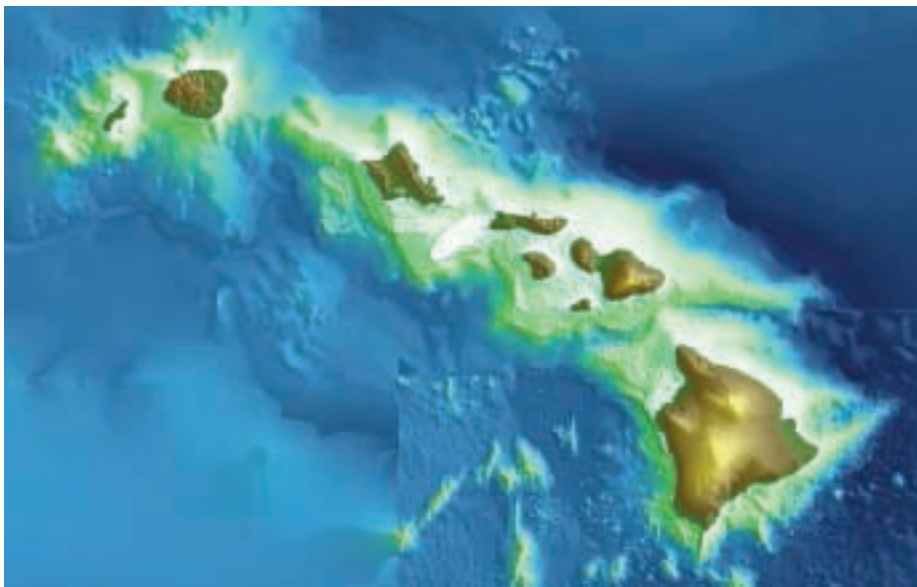
The Key to Hawaii's Economic Future



Millennium Edition
2001

SCIENCE & TECHNOLOGY

The Key to Hawaii's Economic Future



Millennium Edition



Department of Business, Economic Development & Tourism
State of Hawaii
2001

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The 3-D image of the eight major Hawaiian Islands portrayed on the cover and title page of this report illustrates the land topography and seafloor bathymetry compiled on a 9-second resolution grid, using Wessel and Smith's GMT-System at the School of Ocean and Earth Science and Technology (SOEST), University of Hawaii. The data were compiled by Dr. J.R. Smith and T. Duennebier.

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PREFACE

Just a little over two years ago (Fall 1998), the Hawaii State Department of Business, Economic Development & Tourism issued the first edition of this publication, entitled *Science and Technology: the Key to Hawaii's Economic Future*. One might question the utility of a document being revised so soon after its initial publication, which brings to mind an anecdote about Albert Einstein, who was renowned at Princeton for his teachings of postgraduate physics. The nature of his questions on the year-end exams were so cerebral that they would be passed around the campus when the test was over. One year when he handed out his finals, a student raised his hand and said, "Professor Einstein, I think there's a mistake here. You've handed out last year's exam questions." To which Einstein replied, "That's okay. All the answers are different!"

And that's what this report is all about. Many of the challenging questions related to economic development are perennial: how to best utilize society's resources to grow the economy, meet people's needs, and improve the quality of life. But scientific research and technological advance are progressing so rapidly that many of the answers proposed to these questions have changed dramatically over just the past few years.

Today the climate for technology-based growth has accelerated, though challenges remain to be met and potentials to be realized. Hawaii has taken an active role in providing numerous tax and other incentives to support the expansion of existing and growth of new tech-based industries. The private sector has supported this movement by establishing a strong and visionary Hawaii Technology Trade Association. And Hawaii's universities and community colleges have established workforce development programs and collaborative partnerships with the business sector to better meet the short- and long-term needs of industry.

The bulk of this report provides a general overview of Hawaii's key assets and resources that are facilitating Hawaii's progress in science and technology, including some specific examples from each industry sector. These, in turn, suggest additional areas and potentials for further growth. As will be seen, many Hawaii-based enterprises are already very active in pursuing these opportunities. However, this report is not intended to be a complete listing of all science and technology business or research in the state, and inclusion or omission of specific initiatives does not imply official endorsement or lack thereof.

This report concludes with excerpts from several State documents that highlight Hawaii's assets and strategic advantages for technology-based development, including various tax and other incentives that promote such activity. The final section provides a listing of institutional and infrastructural support facilities that currently operate to support technology-based enterprise statewide.

Collectively, it is hoped this information will provide a useful window into the various elements and dimensions that make Hawaii a vibrant center for scientific discovery and technological innovation, as well as reinforce the notion that Hawaii is not only a quality environment for living and relaxation, but also an ideal venue in which to do research, conduct technology transfer, and achieve both successful commercialization and sustainable growth.

— The Editors

For quite some time, I have been convinced that we in Hawaii have all the ingredients for promoting scientific research and technological advances – unparalleled natural resources, a unique and strategic location, state-of-the-art infrastructure, and an exceptionally talented workforce. I therefore have set the development of our technological capabilities and our knowledge-based facilities as prime goals for reinvigorating our state’s economy.

In 1997, I convened the State’s first biotechnology conference, and in 1998, a gathering of information technology leaders in academic research, technology enterprise, and venture finance, to explore the far-reaching potential of science and technology in Hawaii. Since then, I, along with key members of my cabinet and our local business community, have visited technology-oriented firms, institutes, and conventions on both the U.S. and Asian sides of the Pacific. Throughout, our message has been clear: In those areas where our natural assets, knowledge and expertise give us a competitive advantage, we seek to establish new technology-based enterprise and collaborative partnerships.

In this effort, we will compete; but our competition will focus on meeting the high standards and goals we set for ourselves, not simply on emulating areas that appear to be making headway in a race for new riches. We will seek economic growth, but this development must not take place at the cost of resource depletion or environmental deterioration. It also must be growth that employs our best minds and most effective skills toward pioneering new avenues for improving our quality of life.

Additionally, part of our challenge will be to expand and strengthen our knowledge-based infrastructure. This means we must invest in and enhance world-class education, training, research and development. This also means that workers must upgrade workforce skills, and that companies must provide both labor and management with productive, cutting-edge tools that will enable them to succeed with the growth of the Internet and the global digital economy.

Our mission is to create a society that is knowledge-rich, technologically proficient, and globally competitive. In so doing, we will surmount the challenges and capture the benefits of a new economy where risk, uncertainty, and constant change are the rule, rather than the exception. Science and technology are playing a seminal role in advancing this mission, and will continue to serve as catalysts for growth among Hawaii’s industries of the future.

Looking ahead, we need to reach out to scientific advance and technological innovation for new methods and new enterprise which can keep us at the global “cutting edge.” Technology development is an area in which government must exercise leadership to facilitate this achievement. However, this effort also must continue in partnership with the private sector. In addition to the rewards of a healthy economy, the common thread uniting these partners is the knowledge that the future of our children and their children in these islands will depend upon how well this partnership succeeds.

— Benjamin J. Cayetano
Governor of Hawaii



Governor Benjamin J. Cayetano

FOREWORD



Dr. Seiji F. Naya

INTRODUCTION

Science and Technology: *The Key to Hawaii's Economic Future* highlights our strong and continuing efforts to support the growth of advanced technology enterprise in the state through university research, infrastructure development, labor force training, and community outreach programs. These initiatives are developing through partnerships between the private and public sectors in Hawaii and are being structured around the state's existing technology resources and competitive advantages.

Hawaii's continued economic growth in the 21st Century may be determined in large measure by how well we use science and technology to increase our productivity and become a center for technological innovation in the Pacific. As tourism settles into an era of more modest growth, an expanded technology sector is becoming a new catalyst for development, generating new export products, raising Hawaii's profile in the worldwide technology community, and helping attract interest and investment to the state as a site for serious scientific and technological activity. Moreover, an expanded technology base will help support the spread of new technology into Hawaii's industries, which is critical for ensuring a globally competitive economy.

Hawaii is well positioned to compete in a broad range of science and technology-based endeavors. Given our state's strategic mid-Pacific location, we are ideally situated to serve as a bridge to Asia-Pacific markets. Our trans-Pacific fiber optic and satellite connectivity make our island community an increasingly important node on the global information superhighway. Our high-speed data processing and supercomputing facilities give us parallel processing capabilities that can serve a broad range of industries (e.g., medicine, astronomy, global climate modeling and coastal resource management, disaster management, geographical information and global positioning systems, ship design, telecommunications, national defense, and education). We are home to the world's premier sites for research, demonstration, and development in astronomy and astrophysics, oceanography, and geophysics. And our universities are becoming national leaders in many research and development endeavors.

Given these particular strengths, as well as technology-based initiatives already underway, Hawaii's best prospects for the development of an advanced technology sector lie in the areas we highlight in this publication: information technology, telecommunications, biotechnology, health care & medical technology, astronomy & space science, ocean science & technology, environmental technology, renewable energy, and dual use (military/civilian) technology.

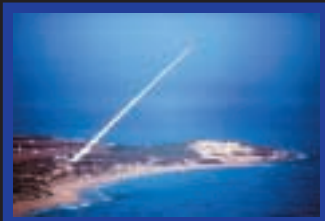
It is important to emphasize that the State's determination to develop the technology sector is not a pipe dream, political rhetoric, or simply pursuit of a fad. Research clearly shows that the application of technology, innovation and labor skills to the production of goods and services can significantly increase productivity and competitiveness in the economy.

In sum, I believe that by working together, government, business, and academia can jointly create a knowledge-based economy in which the keys to job creation and higher standards of living will be creative ideas and adaptive technologies embedded in both services and products.

— Seiji F. Naya
Director

HAWAII'S STRATEGIC SCIENCE & TECHNOLOGY RESOURCES

The Pearls of Paradise



Pacific Missile Range Facility



Hawaii Institute of Marine Biology



Maui Space Surveillance Complex



The Kapolei Teleport



Mauna Kea Observatories



**"Honolulu"
Transgenic Mice**



**The IBM Power3
Supercomputer**



**Pisces V
Underwater Vehicle**

ASTRONOMY & SPACE SCIENCE

Monitoring the Cosmos - Far and Near

Courtesy Richard Wainscoat - IFA/UH



The Mauna Kea Observatories - In the foreground on the summit ridge, from left to right, are the **UH 0.6-meter telescope** (small white dome), the **United Kingdom Infrared Telescope**, the **UH 2.2-meter telescope**, the **Gemini Northern 8-meter telescope** (silver, open) and the **Canada-France-Hawaii Telescope**. On the right are the **NASA Infrared Telescope Facility** (silver), the twin domes of the **W.M. Keck Observatory**; behind and to the left of them is the **Subaru Telescope**. In the valley below are the **Caltech Submillimeter Observatory** (silver), the **James Clerk Maxwell Telescope** (white, open), and the assembly building for the **Submillimeter Array**.

OPENING WINDOWS TO THE COSMOS

Courtesy IFA/UH



The Quest to Understand – Astronomers search for scientific answers to some of humanity's most fundamental questions: How and when did the stars, planets, and galaxies form? What threats do we face from the sun and other celestial bodies? What will be the ultimate fate of the universe? Scientists at the **Institute for Astronomy** study the heavens in an attempt to answer these and other questions.

The clear skies and stable air above Hawaii's volcanic peaks make the state a premier location for astronomy and astrophysics. Today, the Hawaiian islands host the largest collection of professional telescopes anywhere in the world.

- ◆ **More than \$800 million has been invested** in developing major observatories at Mauna Kea on the Island of Hawaii, and at Haleakala on Maui.
- ◆ **Advanced communications technologies using fiber optic networks and satellite relays** allow astronomers to access these telescopes through remote viewing techniques.

Supporting these impressive facilities is the internationally acclaimed faculty at the University of Hawaii's **Institute for Astronomy (IfA)**, as well as its well-trained technical staff and students. Founded in 1967, the Institute conducts investigations in astrophysics and planetary science and is responsible for developing and managing the **Mauna Kea Science Reserve** and the **Haleakala High Altitude Observatory Site**. It also operates solar and laser-ranging facilities on Haleakala and several observatories on Mauna Kea.

IfA is one of the world's leading astronomical research centers. Its broad-based program includes studies of the sun, planets, and stars, as well as research on interstellar matter and galaxies.

Most IfA astronomers use the giant telescopes atop Mauna Kea and Haleakala to collect faint visible light, as well as infrared and submillimeter radiation, from distant objects. They also use and support space observatories, such as the **Hubble Space Telescope** and **Chandra** (an X-ray astronomy satellite), to make observations that cannot be made from the ground. In addition to performing research, some astronomers design and build new instruments to measure and analyze the radiation collected by the telescopes. Other IfA scientists develop theories that explain the observations made by their colleagues.

The lion's share of research at the Institute for Astronomy is funded by the federal government, largely by competitive grants from **NASA**, the **National Science Foundation**, and other federal agencies. However, the salaries of many IfA astronomers, especially those who teach, are included in the University of Hawaii budget funded by the State of Hawaii.



The **NASA Infrared Telescope Facility (IRTF)** is the only astronomical observatory in the world whose principal raison d'être is to support NASA's interests in exploration of the solar system. IRTF provides complementary data required for NASA space flight mission planning, and affords astronomers both facilities and state-of-the-art instrumentation to carry out studies of the solar system. IRTF also provides time for NASA's "Origins" project and other space research initiatives.

Courtesy IFA/UH

The scope and breadth of research conducted atop Mauna Kea, Mauna Loa, and Haleakala are truly astronomical, including:

Galactic and Extragalactic Studies - Observational astronomy studying the property of galaxies and their evolution, as well as multispectral imaging of quasars and radio galaxies.

Star Formation/Interstellar Matter - Surveys of young stars and star clusters to determine the physical conditions in star-forming environments.

Solar Physics - Studies of solar flares and investigations of the sun's magnetic field and corona.

Stellar Astronomy - Spectral studies of low-mass stars and brown dwarfs, and investigations of coronal emissions.

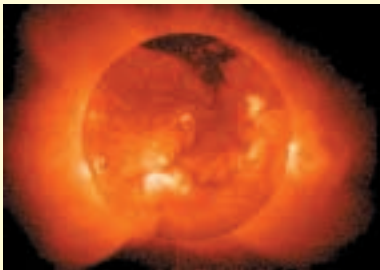
Solar System Studies - Investigations of behavioral differences between new and periodic comets, planetary atmospheres, and ring studies.

Theoretical Studies - Surveys and modeling of galaxy interactions and induced star formation.

Lunar and Satellite Ranging - Monitoring of earth resources and climatic factors; measurements of ocean level and temperature changes, as well as tectonic plate movements.

Some of the most significant discoveries by astronomers utilizing Hawaii's state-of-the-art facilities include:

Courtesy IFA/UH



Astronomers study the sun to understand how changes at the sun's surface affect the flow of energy and radiation to Earth, as well as to develop models for understanding other stars. The main instrument used at Hawaii's **Mees Observatory** atop Mt. Haleakala is the **Imaging Vector Magnetograph**, which allows astronomers to measure the electric currents passing through selected regions of the sun's surface. Electric currents are closely tied with magnetic fields on the sun and are a key to understanding what goes on both below and above the sun's surface.

- ◆ *Astronomers using the largest optical and infrared telescopes in the world have found the most distant known object in the cosmos* — a young galaxy in existence when the universe was only 6% of its present age, and nearly 90 million light-years farther away than any previously discovered. This finding provides clues on how and when galaxies were formed.

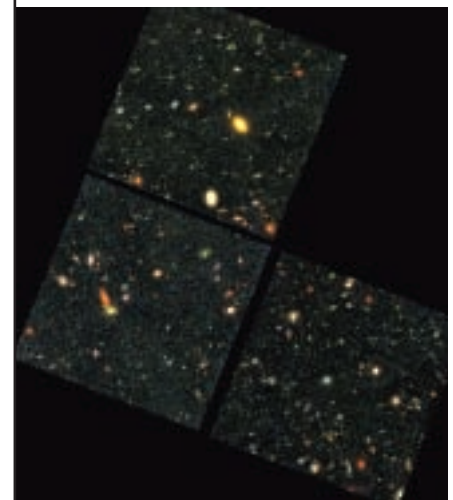
- ◆ *The clearest evidence yet of a budding solar system around a nearby star.* According to astrophysical authorities, the finding represents a “missing link” in the study of how planetary systems are born and evolve.
- ◆ *One of our sun's nearest neighbors – a star just 15 light years from Earth – possesses a planet 1.6 times as massive as Jupiter.* As with other planets recently discovered, this object was not imaged, but betrayed its presence through its gravitational tug on its parent star.
- ◆ *A gamma-ray burst occurring in a distant galaxy,* which settled one of the major controversies about the origin of these enigmatic occurrences. This was a spectacular cosmic event, far more energetic than a supernova explosion.



Courtesy Richard Wainscoat - IFA/UH

The twin 10-meter **Keck Telescopes** on the summit of Mauna Kea constitute the world's largest optical and infrared observatory, allowing astronomers to explore the universe with unmatched power and precision. Representing a capital investment of more than \$170 million, each telescope is eight stories tall, weighs 300 tons, and is equipped with a revolutionary primary mirror composed of 36 hexagonal segments that work together as a single reflector. Both telescopes are now operational, and together give astronomers the ability to resolve stellar objects as though they were using a single mirror 85 meters in diameter. The Keck mirrors are controllable to an accuracy of 30 nanometers and have allowed scientists to view extremely distant galaxies down to the 28th magnitude.

EXTRATERRESTRIAL RESEARCH



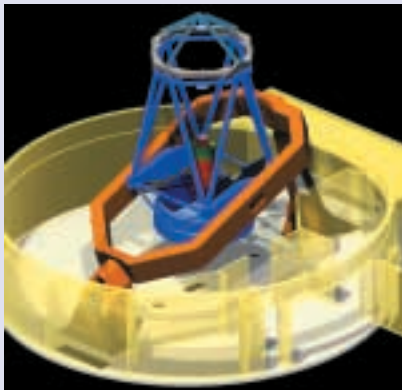
Courtesy IFA/UH

Hawaii Deep Space Survey – The University of Hawaii 2.2-meter telescope and the spectrographs on the **Canada-France-Hawaii** and **Keck Telescopes** were used to carry out one of the first extremely deep surveys of all the galaxies in a representative part of the sky. These surveys have found colors for many hundreds of galaxies out to redshifts beyond 2 (two-thirds of the way across the known universe).



This infrared image of the famous **Orion Nebula** (Messier 42), located 1,500 light years away from Earth, was captured during the “first light” of the **Subaru Telescope** in January, 1999. At the center of the image is the Trapezium – a group of four bright stars, around which younger stars are embedded in the Orion molecular cloud. The blue, faint, and diffuse emission extending over the entire region is due to hot gas ionized by strong ultraviolet radiation emitted by the Trapezium stars.

DETECTOR DEVELOPMENT



The 3.8m **United Kingdom Infrared Telescope (UKIRT)** is the largest telescope in the world dedicated solely to observations at infrared wavelengths between 1 micron and 30 microns. Like all large modern telescopes, UKIRT is a reflecting telescope. Infrared and visible radiation from an astronomical

object (e.g., a star) is collected, reflected and focused by a concave primary mirror 3.8m in diameter. Just before it gets to the focus, a smaller convex secondary mirror at the top of the telescope reflects this steeply converging beam of radiation and directs it downwards, now converging much more slowly, through a central hole in the primary mirror to a flat tertiary mirror below, which directs it to one of four instrument focal stations. Research being done at UKIRT includes topics such as the planets, moons, asteroids and comets within our solar system, star formation and stellar evolution within our galaxy; interstellar gas in our galaxy and others, the properties of normal and active galaxies, and the early evolution and ultimate fate of the universe. The telescope owned by the **United Kingdom Particle Physics and Astronomy Research Council** and operated, along with the **James Clerk Maxwell Telescope (JCMT)**, by the staff of the **Joint Astronomy Centre**, located in Hilo.

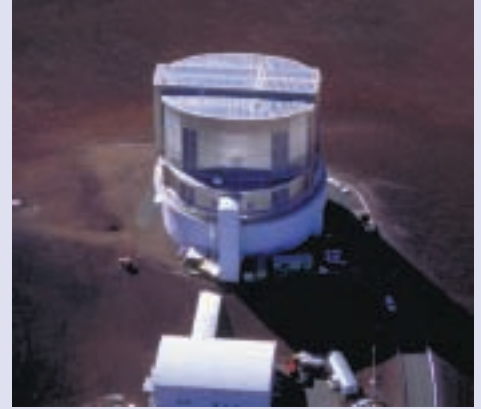
All the major instruments on the University of Hawaii’s own telescopes (the 2.2-meter on Mauna Kea and the Mees Observatory on Haleakala) have been built in workshops at the Institute for Astronomy. So, too, the cameras and spectrographs used on the 3-meter Infrared Telescope Facility (IRTF) that IfA operates for NASA on Mauna Kea.

The Institute for Astronomy is currently building **four major infrared instruments** for Hawaii telescopes, including detectors for both of the new 8-meter telescopes atop Mauna Kea. For each of these projects, IfA has been awarded a contract to design and construct the instrument, as well as to provide the computers and software needed to operate it.

The “retina” of a present-day astronomical camera is a large electronic chip made of silicon. Over the last few years, there have been enormous improvements in both the sensitivities of these detector chips and in the number of pixels they contain.

Development of chips requires cooperation between commercial electro-optical companies and the astronomers and engineers at IfA. While the chips themselves are produced on the U.S. mainland, the tasks of adapting them for use in astronomical situations and maximizing their sensitivity to faint light sources is performed at the University of Hawaii.

The **Optical Detector Group** at IfA develops and maintains the general-purpose charge-coupled device (CCD) cameras used by observers on the UH telescopes. In addition, the group has pioneered the development of ultralarge-format CCD mosaic focal planes, and has built two of the world’s largest-format astronomical CCD cameras. This camera was initially installed at the prime focus of the **Canada-France-Hawaii Telescope (CFHT)**, and is now used regularly on the UH 2.2-meter telescope for wide-field projects such as weak gravitational lensing, the study of faint galaxy statistics, and the search for new solar system objects.



One of Mauna Kea’s newest observatories, the **Subaru Telescope Facility**, represents a new class of revolutionary telescopes. Its ultra-thin and light mirror permits extremely high accuracy in tracking celestial objects. It also employs a new type of computer-controlled enclosure that accommodates the best observational conditions for the telescope. Subaru is observing quasars and radio galaxies in deep space, almost to the horizon of the expanding universe, so as to provide information concerning the origins of the large-scale structure of the universe, as well as its basic properties such as the curvature of space, leading to a comprehensive history of the universe.

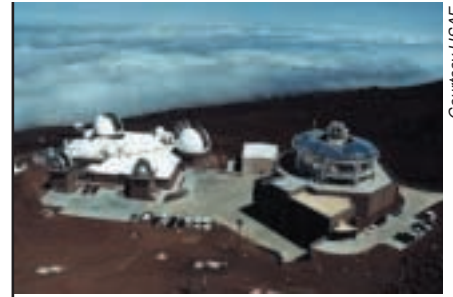


Dr. Gerard Luppino with the 8,192-by-12,288-pixel camera built for the **Canada-France-Hawaii Telescope**. The focal plane measures 12 cm x 18 cm and contains twelve CCDs in a 2 by 6 pattern.



Gemini North, one of the largest telescopes in the world, was built by an international partnership of seven nations. It is the first of two 8-meter telescopes that together can explore the entire northern and southern skies in optical and infrared light. Its twin, Gemini South, is under construction on Cerro Pachón in northern Chile. Together, these telescopes are expected to obtain unprecedented optical and infrared views of stars, galaxies, and the most distant outposts of the known universe.

The **Air Force Research Laboratory (AFRL)**, located atop Mt. Haleakala on Maui, has a two-fold mission. First, it conducts the research and development mission on the **Maui Space Surveillance System (MSSS)** at the **Maui Space Surveillance Complex (MSSC)**. Second, it oversees operation of the **Maui High Performance Computing Center (MHPCC)**. The accessibility and capability of the Maui Space Surveillance System provides an unequalled opportunity to the scientific community by combining state-of-the-art satellite tracking with a facility supporting research and devel-

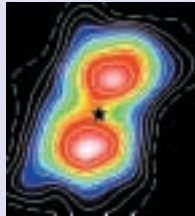


A multifaceted observatory, the **Maui Space Surveillance Complex** combines large-aperture tracking optics with **visible and infrared sensors** to collect data on satellites, orbital debris, and astronomical objects. It supports the Navy's Pacific Missile Range Facility (PMRF) ballistic missile programs, as well as the Jet Propulsion Laboratory's asteroid detection research.

opment. Virtually year-round viewing conditions are possible due to the relatively stable climate. Dry, clean air and minimal scattered light from surface sources enable visibility exceeding 150 km (see also *Defense & Dual-Use Technology*).

SENSING EARTH AND OTHER PLANETS

With a diameter of 15m the **James Clerk Maxwell Telescope (JCMT)** is the largest astronomical telescope in the world designed specifically to operate in the submillimeter wavelength region of the spectrum. Managed on behalf of the UK, Canada & Netherlands by the **Joint Astronomy Centre (JAC)**, the JCMT is used to study our Solar System, interstellar dust and gas, and distant galaxies. Radio telescopes are used to study objects that are invisible to more traditional optical telescopes – especially where dust obscures visible light. Such objects include stars in their earliest stages where they are surrounded by gas and dust disks that have not yet coalesced to form planets (see image above).



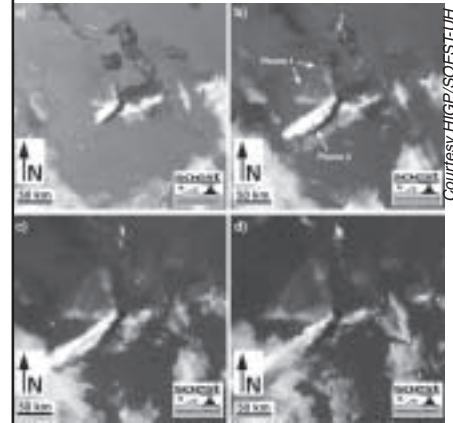
especially where dust obscures visible light. Such objects include stars in their earliest stages where they are surrounded by gas and dust disks that have not yet coalesced to form planets (see image above).

The **Hawaii Institute of Geophysics and Planetology (HIGP)**, a division of the School of Ocean and Earth Science and Technology (SOEST) at the University of Hawaii, is also pioneering the frontiers of space science through **basic and applied research, with special emphasis on remote sensing**. It uses geophysics to study our planet (e.g., through seafloor imaging and mapping), and manages a variety of geophysical service programs for the state.

Additionally, HIGP develops new technologies for **ocean and environmental monitoring and observation** – from imaging spectrometers for spaceborne and airborne observation of volcanic plumes to probes for measuring the physical

properties of seafloor sediments – and performs extensive **studies of our solar system from space** (e.g., analysis of volcanic deformation using radar and the Global Positioning System; spectroscopic studies of the evolution of asteroids, the Moon, Mars, and the moons of Jupiter).

Finally, HIGP is deeply committed to **education and outreach for all ages** and manages the **Hawaii Space Grant College Program**, which focuses on workforce development in scientific and technical fields by providing training workshops and courses for teachers and fellowships for undergraduate students. It also hosts the **NASA Pacific Regional Data Center** that provides images to both the public and professional scientists of all the planetary missions ever flown by NASA.

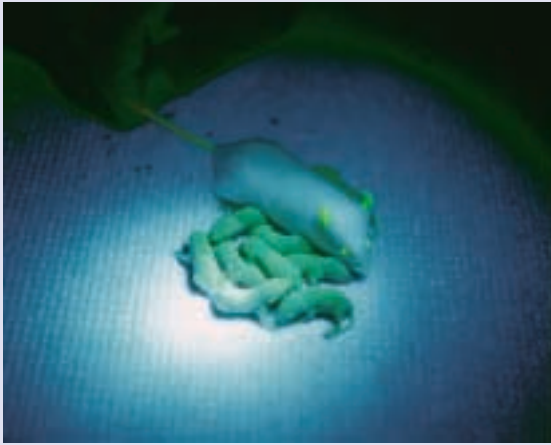


GOES-8 satellite observations, made by SOEST investigators, using data received from the Naval Research lab in California. Images show the first two eruption plumes from Cerro Azul volcano in the Galapagos Islands detected on September 15, 1998. Images were obtained at the following Universal Times: a) 20:28; b) 20:58; c) 21:28; and d) 21:58. Notice that in the final image, the edge of Plume 2 is becoming distorted. The next image in this series (not shown) indicates that the event producing this plume had shut off and that the plume was dissipating. SOEST investigators in Hawaii were able to electronically send information about the eruption to research scientists at the Darwin Research Station in the Galapagos close to 4 hours before word reached them from the field. **These results demonstrate the value of real-time satellite observations made in Hawaii for disaster monitoring and hazard mitigation around the Pacific.**

BIOTECHNOLOGY

From Virus-Free Papaya to Fifth-Generation Clones

Courtesy UH Relations



University of Hawaii scientists, together with colleagues in Japan, have developed an innovative method for producing transgenic mammals. The new technique – **Honolulu transgenesis** – uses sperm to deliver genetic information (DNA) from one organism into the egg of another. This method was demonstrated using DNA from green fluorescent jellyfish protein to make green mice. The introduced DNA contains a gene that directs production of a protein that glows green under long-wave ultraviolet light. Thus scientists could easily see that the jellyfish “green gene” DNA was incorporated into the mouse genome when the mouse appeared green under ultraviolet light. Honolulu transgenesis may be useful in medical research and in the development of xenotransplant donors.

The biotechnology revolution is changing the world. By virtue of its unique combination of natural, scientific and technological resources, Hawaii is helping pioneer the development and production of new, high value-added products and services in various biotechnology areas – including the seed industry, plant tissue cultures, floriculture, tropical fruits and beverage technology, bioprocess engineering, nutraceuticals, phytopharmaceuticals, biomedical products, marine bioproducts, and bioremediation.

- ◆ In light of its **highly favorable climate and ocean setting**, Hawaii is ideally situated to grow and experiment with many different kinds of terrestrial and ocean plants for which markets exist on a global scale.
- ◆ The state is home to hundreds of **trained researchers with expertise in agricultural, medical, and marine research** and poised to transform the offshoots of R&D into commercial products.
- ◆ Local biotech firms are conducting both **basic and applied research in molecular and nuclear biology, as well as immunochemistry**, leading to the genetic engineering of antibodies and other high-value, complex proteins for commercial production.

Biotechnology research in Hawaii takes advantage of the islands’ unique flora and fauna, as well as other natural resources, to produce high-value products whose markets are not constrained by the high cost of overseas shipping.

MEDICAL BIOTECHNOLOGY

Biogenesis research at the University of Hawaii (UH) was internationally recognized in 1998 when Dr. Ryuzo Yanagimachi and his team of researchers produced **the first mouse clone** (see sidebar). They went on to successfully clone five generations of mice and the first male mouse clone. Concurrently, they were able to produce **transgenic green mice** as a visible demonstration of the ability to transfer genetic material from one species to another. **“Team Yana”** is now involved in research that one day may make possible the production of cells, tissues and organs cloned from cells from an individual in need of organ replacement. Cloning may also have important applications in repopulating endangered species and in producing animals that carry desirable traits for production of new pharmaceutical substances, valuable livestock, and production of organs for xenotransplantation.

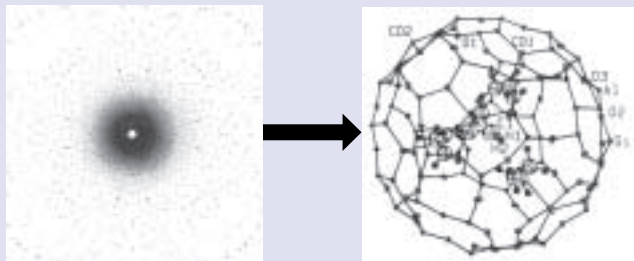
Dr. Sandra Chang and her team of researchers in the **Department of Tropical Medicine and Medical Microbiology at the John A. Burns School of Medicine** are nearing a major breakthrough in their fight against malaria, a mosquito-borne disease that kills over a million people each year in developing countries. The experimental **malarial vaccine**, developed by Chang and her colleagues using recombinant DNA technology, has proven effective in tests with monkeys. UH is patenting the vaccine and working with the World Health Organization and a European pharmaceutical company to produce sufficient quantities of the vaccine for the first human clinical trials that could begin as early as 2002.

UH is also engaged in research on other strains of malaria. For example, Botany professor David Duffy has been awarded a five-year **\$4.1 million grant from the National Science Foundation** to study **avian malaria**, which has led to the extinction of at least 10 species of native birds in Hawaii and poses a threat to another 22. The project brings together researchers in three fields: emerging disease, conservation biology, and invasive alien species.

The State of Hawaii may be on the verge of yet another technological advance linked to revelations in the **science of genomics** – a study of the interactions among genes and proteins which determine how the human body works. Some researchers believe that the human genome, the term for our complete set of genes (now estimated at around 30,000), may provide cells with instructions to make as many as 300,000 different proteins. Over the last few years, scientists at major pharmaceutical companies and a host of smaller biotech firms have turned their attention to such proteins to determine how they work.

Where does Hawaii fit into this process? X-ray analysis can be employed to help scientists work out the shapes of proteins – a key insight for developing effective drugs. Drs. John Madey and Eric Szarmes at the University of Hawaii's **Free Electron Laser (FEL) Laboratory** have developed a process utilizing a nonsynchrotronous high energy light source for **x-ray crystallography** and **x-ray microscopy**.

Courtesy Eric Szarmes



The image on the left is an **X-ray diffraction pattern** similar to those produced by the **Free-Electron Laser**. Such images are used to decipher the **3-dimensional molecular structure** of compounds such as the cyclopropane complex of dehydrated Cd²⁺-exchanged zeolite A illustrated on the right.

This technology would enable researchers to gain a **three-dimensional perspective and understanding of molecules** – a stereographic view that complements the chemist's molecular formula and enhances understanding of how proteins are structured, and thereby how they are likely to bond and react with other substances.

Such information would be extremely useful for companies wishing to manufacture effective drug therapies for a broad range of maladies.

For example, **smaller, cheaper free-electron lasers (FELs)** could be used **surgically to destroy tumor cells while leaving surrounding healthy tissues unharmed**. Such lasers can be tuned to cut tissue with minimal pain, and used to treat severe

Courtesy Jim Crisafulli



Research on the **Free-Electron Laser** is being spearheaded by a 5-member team through the **University of Hawaii's Department of Physics & Astronomy**. Team members, pictured above from left, include UH Research Scientist Teng Chen, Ph.D. candidate Frank Price, Professor John Madey, Associate Professor Eric Szarmes, and Princeton undergraduate Orion Crisafulli.

wounds and burns. **The ability of FELs to analyze molecular structures could be used to produce synthetic chemicals as well as to examine viruses like HIV for potential weaknesses**. The great promise is that this next generation of FELs will become even more compact and cost-effective, enabling them to be used as standard equipment in hospitals and research universities nationwide.

ADVANCED LASER RESEARCH



Courtesy John Madey

The **Mark III infrared FEL** was designed and constructed in 1984 by Professor John M.J. Madey and his group at Stanford University for medical and materials science research in the mid-IR (~2 μm to ~10 μm), and is ideally suited as a testbed for novel FEL concepts and experiments as well as for the training of graduate students. This FEL has **important applications in chemistry and ultrafast IR spectroscopy**, and is being further developed by Professor Eric B. Szarmes for unique applications in high-resolution nonlinear spectroscopy and remote sensing. The University of Hawaii has also acquired and will be installing the **Mark IV FEL** from Boeing, which was constructed by Rocketdyne in 1988 for experiments in high power FEL MOPAs at Stanford University (using the Mark III FEL as the master oscillator). This FEL will be re-commissioned by the **Hawaii Institute of Geophysics and Planetaryology** at the UH Manoa campus for eventual use as a **portable, broadband and extremely high-powered, tunable UV to IR source (0.3 μm to 15 μm)** for shipboard remote sensing of the atmosphere.



Biomedical research in Hawaii takes advantage of the islands' unique flora and fauna, as well as other natural resources, to produce high-value products whose markets are not constrained by the high cost of overseas shipping. Above, a researcher at the **Hawaii Biotechnology Group** works in a biosafety cabinet with genetically-modified cells producing Dengue Virus proteins.

AGRICULTURAL BIOTECHNOLOGY



Genetically-engineered papaya, developed by University of Hawaii researchers, that is resistant to the Papaya Ringspot Virus.

The **Hawaii Biotechnology Group, Inc. (HBG)** uses its strengths in genetic engineering, immunology, and chemistry to address major unmet human health needs in the areas of infectious disease, inflammation, cancer, and drug discovery. Founded by University of Hawaii science and business professors in 1982, HBG has received more than **\$30 million in research funding** from the National Institute of Health, the Department of Defense, the State of Hawaii, and other state and federal institutions, and is now poised to capitalize on this strong scientific foundation with a program designed to commercialize this technology. Its current programs include:

- ◆ **Development of a recombinant, sub-unit vaccine for dengue fever** - a disease found primarily in tropical and subtropical areas around the world with tens of millions of cases annually.
- ◆ **The ROS (“reactive oxygen species”) Program** to develop FDA-approved therapies targeted to intervene in the cascade of the highly damaging biological events that occur as a result of oxidation in large, poorly served disease states.
- ◆ **Combinatorial libraries** of novel compounds from naturally occurring, bioactive compounds that could prove to be more effective lead compounds than those from traditional combinatorial sources.
- ◆ **Detection systems using ultra-sensitive assays** for identifying pathogens from infectious agents in foods and the environment. A novel biosensor technology is being created to detect a bacterium that causes dysentery.
- ◆ **Early-stage “pipeline” programs** that utilize “prodrug” technology to minimize side effects and maximize efficacy in the treatment of fungal infections and cancer.

Scientific advances at the **University of Hawaii’s College of Tropical Agriculture and Human Resources (CTAHR)** and other Hawaii-based public and private institutions have provided the state with a basis not only for further breakthroughs in research, but also for commercialization and economic diversification.

Exemplary of Hawaii’s leadership in biotechnology is the development of a **genetically engineered, disease-resistant papaya** to stem the recurrence of a “ring-spot” virus that is threatening production of this fruit on the Big Island. Developed by CTAHR in collaboration with **Cornell University** and the **Upjohn Company**, the new crop is planted, harvested, marketed and consumed like any other crop, demonstrating a high-tech solution with a low-tech application. The joint papaya ringspot virus research project provides a model for other genetic engineering research programs. Excellent progress has been made on a molecular immunization project that could help protect banana, pineapple, and other Hawaii fruit crops from viral diseases.

Several large companies in Hawaii currently grow **seed crops enhanced by biotechnology**. These companies include all of the major seed companies in the United States: **Monsanto, Cargill, Syngenta Seeds Inc., Pioneer Hi-Bred International Inc.,** and **Garst Seed Company**, a subsidiary of the **Advanta Group** – a Netherlands/UK consortium that is the fourth-largest seed company in the world. A major reason these companies are investing in Hawaii is the recognition that the state is one of the leading centers for plant genetics in the world. The islands’ highly predictable weather and climate combine to yield a low-risk environment for developing new plant varieties. Under normal conditions on the Mainland, it can take up to 12 years to develop a new variety of seed. In Hawaii’s climate, with up to three crops possible per year, this process can be reduced to four years or less.

Hawaii's worldwide reputation as the foremost grower of anthuriums was enhanced when a species called 'Tropic Fire' – developed by UH professor Heidi Kuehnle – was granted a patent. Sales have been excellent. Royalties are being returned directly to the research program for continued breeding work, which has produced two more species on which patents are pending. It is estimated that the demand for 'Tropic Fire' will eventually reach more than a million plants.

Agricultural biotechnology is not limited to work on crops. Finding and **eliminating termite nests** will become easier, thanks to research performed by CTAHR entomologists J. Kenneth Grace and Claudia Husseneder. Using state-of-the-art genetics techniques, such as DNA fingerprinting (the same method used to recognize individuals and establish paternity in humans), they can define the boundaries of a termite colony and monitor the spread of toxicants throughout the colony to verify that a bait is working. If pests reappear after treatment, the techniques can be used to determine if the infestation is new or a recurrence. Working with CTAHR scientists, commercial exterminators will be able to use this information to select effective baits and optimize placements to control a pest that causes more than \$100 million damage annually in Hawaii.

The **Hawaii Agriculture Research Center (HARC)**, located on the island of Oahu, is a private, non-profit organization specializing in horticultural crop research including agronomy and plant nutrition, plant physiology, breeding, genetic engineering and tissue culture, and control of diseases and pests through integrated pest management. HARC also performs pesticide registration work; training in areas such as pesticide application and environmental compliance; ground water monitoring; and technical literature searches.

Mainland seed companies take advantage of Hawaii's favorable weather conditions by utilizing HARC's field and nursery services for winter growouts, seed increases, and testing. The **analytical chemistry laboratory** specializes in residue studies conducted according to EPA Good Laboratory Practices. The **environmental services group** offers evaluations for compliance with environmental regulations and assessments for Best Management Practices. HARC produces and sells seed of supersweet corn and leucaena developed by the University of Hawaii and HARC.

HARC's biotechnology team utilizes techniques such as **gene transformation** through particle bombardment and/or agrobacterium to achieve insect and disease resistance to solve production problems and genome mapping to enhance breeding programs. Currently, genetic transformation projects focus on sugarcane, pineapple, coffee, and papaya. **Genome research** has expanded from sugarcane to other tropical fruits such as papaya, coffee, macadamia nuts, and pineapple. **Tissue culture protocols** were developed and are currently used for plant regeneration and micropropagation of a wide range of plants including sugarcane, pineapple, banana, taro, and woody species such as Eucalyptus and Acacia. **Cellular and molecular biology research** is also conducted under funds received through the USDA. This program mainly sponsors graduate students at the University of Hawaii and post-doctoral researchers collaborating with USDA scientists at HARC. Projects include improving transformation efficiency through investigation of promoters, reducing variability of transgene expression, and increasing sucrose accumulation through cell transformation with constructs which alter soluble acid invertase activity.



"Tropic Fire," a potted anthurium variety developed and patented by CTAHR researchers, is expected to sell up to one million plants over the years.

Courtesy CTAHR/UH



Courtesy HARC



Above, **HARC** researcher Dr. Ray Ming loads a gel with DNA in a study of **genetic diversity in coffee**. To the left, Dr. Chifumi Nagai (right) and Dr. Liwen Xiong collaborate on development of a **Pineapple Transformation System**.

MARINE BIOTECHNOLOGY

Courtesy MarBEC



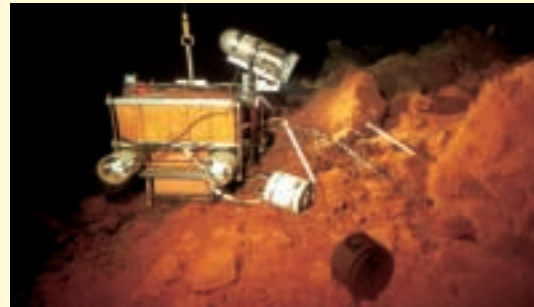
The exploitation of new marine bioproducts requires scientists and engineers with backgrounds in marine science. The education of chemical engineering, ocean engineering, and biology students in marine biotechnology is a major component of MarBEC. These cross-trained students will be the new professionals entering the emerging marine biotechnology industry. Above, MarBEC Summer Undergraduate Research Intern Lena Asano presents her research project in a video-conferenced symposium with MarBEC partner University of California, Berkeley.

Courtesy NELHA



Situated at Keahole Point, NELH provides year-round intense sunlight, minimal rainfall, and nutrient-rich deep sea water that enables ocean and energy-related companies to pursue research and commercial development. The parallel green and red raceways in the picture above are being used by the Cyanotech Corporation to grow microalgae for nutraceuticals.

The **Marine Bioproducts Engineering Center (MarBEC)**, a National Science Foundation Engineering Research Center, represents a partnership between the **University of Hawaii at Manoa** and the **University of California at Berkeley**, with additional collaboration from leading national laboratories, research centers, and museums. MarBEC is building a foundation of applied research, education and technology transfer to support a marine biotechnology industry of increasing commercial and national importance. Employing a systems focus, MarBEC integrates product discovery, large-scale cultivation and separation, purification and formulation technologies. MarBEC supports this growth through collaborative activities designed to advance:



Courtesy MarBEC

The fact that some microorganisms may be found only in physically and/or chemically extreme environments complicates the detection and isolation of novel products. To address this challenge, MarBEC is developing techniques to sample (above), cultivate and subsequently screen microorganisms from such environments, and to manipulate bacterial and microalgal genes.

- ◆ Discovery and extraction of novel bioresources.
- ◆ Separation, characterization and purification of useful bioproducts.
- ◆ Development of efficient production systems.
- ◆ Formulation and delivery of stable bioproducts to market.

The focus of MarBEC's interactions with the private sector is the **Industry Sponsor Program (ISP)**. This program is intended to maximize intellectual dialogue and technology transfer between MarBEC researchers and industry. By building strong industry relationships over the next several years, MarBEC will enhance its adaptability and responsiveness to industry needs. With industry support, MarBEC will continue to provide new opportunities to researchers, students, and companies in the marine bioproducts field.

The **Natural Energy Laboratory of Hawaii**, or **NELH**, located at Keahole Point on the west coast of the island of Hawaii, was developed to provide resources and facilities for energy and ocean-related research, educational, and commercial activities. At the 600-meter depth, the temperature of the seawater off the Keahole coast is approximately 6° C. This extremely cold seawater can be used for a variety of purposes which warm the seawater without altering its other properties. It also resides below the photic zone of the ocean. Without sunlight, there is no primary productivity; thus there are very few living organisms, producing a virtually pathogen-free environment. The deep sea water also has significantly elevated levels of inorganic nitrates, silicates and phosphates, compared to the nutrient-deficient surface water. These nutrients are necessary for sustained growth of both microalgae and macroalgae.

Today, NELH is the only place in the tropics where cold seawater is being pumped ashore. It is also the only location where R&D is being performed on the commercial potential of deep ocean water for energy production, air-conditioning, industrial cooling, cooled tropical agriculture, and a wide range of unique aquaculture projects.

NELH's tenants include aquaculture enterprises as well as companies specializing in marine biotechnology and mariculture. **Cyanotech Corporation** is currently the world's largest producer of *Spirulina* – a high value nutritional supplement for the health food industry. **Aquasearch, Inc.'s** photobioreactor technology is used for *astaxanthin* production and other microalgae research and development that will provide opportunities for pharmaceutical applications. **Kona Cold Lobster Ltd.** boasts the largest holding facility for Maine lobsters west of New England; **Royal Hawaiian Sea Farms** produces over two tons of sea vegetables per week.

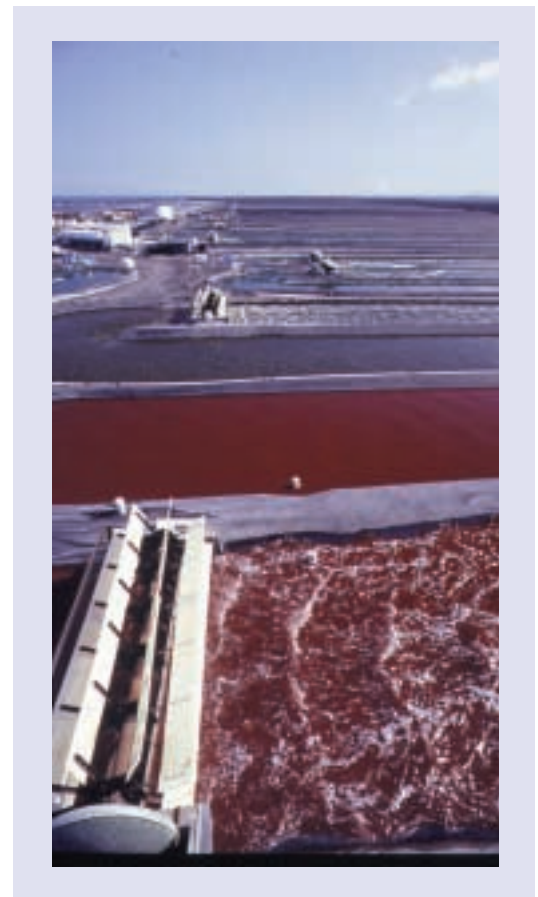
Common Heritage Corporation, led by NELH founder, Dr. John Craven, is growing more than 100 fruits and vegetables in soil cooled by pipes carrying deep seawater. Temperate crops, such as strawberries, asparagus, grapes and carrots, do very well under the climate control that is available by varying the flow rates of the cold seawater to create a "perpetual springtime". Pineapple, which normally takes two years to mature in Hawaii, gets extra nutrition from the cold soil and produces sweet fruit in only nine months.

An affiliate program of NELH since 1995, the **Center of Excellence for Research in Ocean Science (CEROS)** has brought over \$50.2 million of federal Department of Defense research funds to Hawaii for the development of novel technologies with dual military and civilian uses. Over 100 successful projects have been funded to date, including innovative ship designs for smoother and faster rides, an antibiotic extracted from a marine alga for the treatment of staph infections, a scuba diver homing device, and a bottom-penetrating sonar system used to map offshore sand deposits and locate buried pipelines. **Black Pearls Inc.** was awarded \$173,201 from CEROS for development of an efficient way of producing phytoplankton in a bacteria-free environment.

Taylor Resources, Inc., and **Coast Seafoods Company**, the U.S.'s two largest producers of oysters and Manila clams, have each developed extensive shellfish nursery operations at NELH. From the Pacific Northwest, they bring "spat", just settled larvae less than 1 mm in size, to NELH for a two-month grow-out in Kona's clean water and abundant sunshine. The animals are returned home after a two-month Hawaiian vacation – ready to enter the ocean a full year earlier than if they'd stayed home in the Northwest.

The **Big Island Abalone Company (BIAC)**, a 40-acre aquafarm that anticipates producing up to 10 percent of the world's premium abalone, has developed a high-tech system to grow premium abalone using deep-sea water and advances in marine biology.

Finally, **Marine Bioproducts, Inc.** is planning for a new 10-acre site to commercialize production of specialty agar (used in laboratories as a medium for cultivating bacteria, etc.) based on successful research conducted at its current R&D site located at NELH.



Courtesy Cyanotech

A 500,000-liter culture pond at **Cyanotech Corporation**, which currently maintains 67 microalgae production ponds. Cyanotech's *Spirulina Pacifica* is a nutrient-rich dietary supplement sold to health-conscious consumers worldwide.



Courtesy Aquasearch, Inc.

Aquasearch Inc. is a global leader in photobioreactor technology. Industrial photobioreactors are a new, "platform" manufacturing technology that unlocks the commercial potential of microscopic plants – 30,000 species of unexploited microalgae. The **Aquasearch Growth Module (AGM)** is the largest, most cost-effective photobioreactor ever operated.

DEFENSE & DUAL-USE TECHNOLOGY

From National Defense to Civilian Innovation

Courtesy PMRF



PACIFIC MISSILE RANGE FACILITY (PMRF) — Located on the west coast of the island of Kauai, PMRF provides the world's largest multi-environment range capable of supporting surface, subsurface, air, and space operations. Its goal is to facilitate integrated range services using state-of-the-art technology that ensures the safe conduct and evaluation of both training and T&E (testing and evaluation) missions. A thousand square miles of instrumented underwater range and over 42,000 square miles of controlled airspace make PMRF a premier facility for supporting operations which vary from small, single-unit exercises up to large, multiple-unit battle group scenarios. PMRF's relative isolation, ideal year-round tropical climate, and encroachment-free environment help sustain the facility's excellent record for operation completions. The base's proximity to major Department of Defense installations and organizations, as well as to the University of Hawaii's ocean research facilities on Oahu, affords major cost and operational benefits to range users. Transportation of project personnel, equipment, and materials is also easily accommodated via commercial and military transport systems.

Traditionally, federal expenditures have contributed heavily to Hawaii's economy. Although the underlying data and methods of calculation may not be strictly comparable, the federal sector may be regarded as second only to tourism in terms of economic contribution. Current estimates indicate defense spending in Hawaii accounts for 10% of gross state product, versus 20% for tourism.

While these facts are probably well known, the impact of federal expenditures on technological innovation and Hawaii's future growth potentials has not been fully appreciated. This refers to the potential influence of what has been termed "dual-use technology" on productivity and economic progress.

For Hawaii, federally-funded projects and the technologies they develop, particularly in areas covered by Defense appropriations, can help raise the state's productivity level and growth output. With development of these new technologies comes innovation and management skills transfer, which in turn results in a more skilled workforce and a greater potential to support new industries.

Courtesy NASA



Helios is one of several remotely-piloted aircraft being developed as technology demonstrators by several small airframe manufacturers under NASA's Environmental Research Aircraft and Sensor Technology (ERAST) project. This unique craft is intended to demonstrate the ability to reach and sustain horizontal flight at 100,000 feet altitude on a single-day flight, and to maintain flight above 50,000 feet altitude for at least four days – both on electrical power derived from non-polluting solar energy. These capabilities will be tested during future flights in Hawaii at PMRF.

It is particularly significant that federal agencies such as NASA and the Departments of Defense, Commerce and Energy have all focused on programs and facilities that not only meet national security objectives, but also have early and feasible application to civilian and commercial use. The rationale is that industry is afforded opportunities to commercialize government R&D, while federal agencies can draw from a broader commercial technical base and receive royalties, should commercialization result in a viable product or service.

A number of federally-funded programs in Hawaii directly relate to or promote high technology development in the state, including:

- ◆ **Pacific Missile Range Facility (PMRF):** As the largest multi-environmental range in the world, PMRF's capabilities provide a wide variety of simulations for training, research, development, testing and evaluation as well as education endeavors. The Facility was recently approved as the primary test range for Navy missile defense tests of ship-borne defenses. Companies involved in these initiatives include ITT, Sandia Labs, MIT-Lincoln Labs, Boeing, DSR, STI, SAIC, Textron Systems Division, TREX Enterprises, Oceanit Labs, Solipsys Corporation, Northrop Grumman, and Lockheed Martin. PMRF has received in excess of \$500 million over the last four years as approved by the U.S. Congress with the support of Hawaii's senior Senator, Daniel K. Inouye.

- ◆ **Air Force Space Command – Haleakala:** Over the past six years, about \$230 million has been spent to develop, research, and improve atmospheric and space imagery technology atop Haleakala. The **Ground-Based Electro-Optical Deep Space Surveillance (GEODSS)** system at the **Maui Space Surveillance Site** (one of three such sites around the globe) plays a vital role in tracking space objects, particularly those in deep space. Over 1,200 objects, including geostationary communications satellites, are in deep space more than 3,000 miles from earth. GEODSS brings together the telescope, low-light-level television and computers – three proven technologies. The main telescopes have 40-inch apertures and a two-degree field of view. The system only operates at night when the telescopes are able to detect objects 10,000 times dimmer than the human eye can see (and track objects as small as a basketball more than 20,000 miles in space!). Companies utilizing these facilities include Boeing, Textron Systems, TREX Enterprises, and PRC Litton (see also *Astronomy & Space Science*).

- ◆ **Pacific Medical Network (PACMEDNET):** A congressionally-mandated Department of Defense (DoD) automation and telecommunications project, PACMEDNET is designed to **prototype, validate, and “live-test” demonstrate clinical solutions to enrich patient encounter information**. It furnishes medical providers with the tools necessary to review patient historical treatment records that previously have been unavailable from a single source – both eliminating the need for hand-carried medical records as well as the concern over lost or missing patient records.

Other benefits of this network include secure, web-enabled remote access to health information history on demand; increased data integrity; consistent computer-based patient records; assurance of a longitudinal view of patient encounter history; synchronization of patient data from disparate data sources; elimination of time, distance, and enterprise barriers to facilitate provider collaboration; advanced patient data facilitating triage and treatment; and controlled access to remote patient data. **Tripler Army Medical Center** in Honolulu is providing the technical support and administrative coordination to demonstrate this technology and facilitate its deployment to military forces throughout the Pacific. Telemedical technologies and protocols developed through this program are also being transferred to support private medical institutions and research programs in Hawaii.

- ◆ **Center for Excellence in Research in Ocean Science (CEROS):** The CEROS Program was created under a \$5 million grant provided by the **Defense Advanced Research Projects Agency (DARPA)** in 1993. CEROS seeks to advance innovative concepts and new approaches to technology while fully leveraging existing facilities and infrastructure in Hawaii and demonstrating commercial utility for the Department of Defense (DoD). Its mission is to support the DoD technology requirements; encourage leading edge R&D in ocean sciences and technology in Hawaii; foster use of ocean R&D facilities in Hawaii; provide an interface between specialized small businesses with expertise in ocean-related R&D and DoD users of advanced technology; and develop avenues to ocean science expertise and facilities at the University of Hawaii. Since 1993, CEROS Research Programs have funded a total of 116 research and development projects at a total value of over \$46.12 million. The vast majority of grants have been to local businesses such as **Orincon, Makai Ocean Engineering, Pacific Marine, Science & Technology International, and Oceanit Laboratories** (see also *Biotechnology and Ocean R&D*).



Courtesy USAF

The U.S. Air Force (USAF) has begun improving its ability to track 500 deep-space satellites from atop Haleakala by refurbishing three telescopes at the **Maui Space Surveillance Complex**. Above, workers lower the 14,800-pound **Ground Based Electro Optical Deep Space Surveillance System (GEODSS)** telescope onto its new mount.



Courtesy USAF

The Air Force Office of Scientific Research (AFOSR) and the National Science Foundation (NSF) have allocated \$2 million for civilian space research making the **Advanced Electro-Optical System (AEOS)**, the U.S. Air Force’s largest and most advanced telescope system, available to civilian astronomers. Above, Hawaii Senator Daniel K. Inouye greets Dr. Joseph Janni, former director of AFOSR, at a recent technical conference on Maui. The Senator continues to play a key role in helping bring many defense-related programs to Hawaii.



Dedicated on March 2, 2001, the **MHPCC Linux Supercluster** (named “Huinalu”, or “a group of waves”) is one of world’s largest and fastest computer superclusters. Housing 520 processors and with nearly 2,000 processors of **IBM Power3 technology**, MHPCC’s theoretical **peak performance is a staggering 2.36 teraflops** (trillions of scientific calculations per second). MHPCC offers high-speed parallel processing capabilities that can serve a broad range of industries (e.g., medicine, astronomy, global climate modeling, coastal resource management, Geographical Information Systems/Global Positioning Systems (GIS/GPS), ship design, disaster management, fire danger modeling).

- ◆ **The Maui High Performance Computing Center (MHPCC):** Located at the **Maui Research & Technology Park (MRTP)**, MHPCC is a national supercomputing center established by the University of New Mexico through a Cooperative Agreement with the Air Force Research Laboratory. MHPCC offers a large-scale parallel computing platform with both classified and unclassified capabilities, terabytes of disk and on-line tape storage, and a high-speed communications infrastructure that connects directly to the Defense Research and Engineering Network (DREN) and the Internet backbone.

MHPCC supports the research efforts of the Air Force's **Maui Space Surveillance Complex (MSSC)**. To integrate its high performance computing tools with MSSC, MHPCC is developing the Maui Image Manager and Online Systems Archive – a web based environment for processing, viewing, and archiving data collected at the MSSC site (see also *Astronomy & Space Science*). MHPCC also supports the **Pacific Disaster Center** at MRTP (see opposite page), as well as the Pacific Missile Range Facility on Kauai (see previous pages).

From the development of more accurate weather and climate forecasts to advanced manufacturing designs to life-saving pharmaceuticals, MHPCC is uniquely positioned to assist in the migration of basic research to production by offering a state-of-the-art computing environment for prototyping and testing high performance computing applications. MHPCC’s current focus areas include processing data from telescopes, satellites, radar, and other sensors; environmental and disaster modeling and battlefield simulations; and advanced technology workshops as well as the integration of high performance computing technology into the classroom (see also *Information Technology*).

- ◆ **Remote Sensing/GIS:** Federal funds have been appropriated to develop and test multispectral, hyperspectral and imaging radar sensors for a broad range of applications. For example, **TerraSystems, Inc.** at the **Manoa Innovation Center (MIC)** is providing airborne and spaceborne remote sensing imagery and imagery products to managers and engineers involved in environmental monitoring and engineering, coastal assessment, and land use and resource management; and develops, produces and sells the highest-quality digital cameras to support the most up-to-date airborne and underwater mapping and surveying techniques. **Innovative Technical Solutions (ITS)**, also at MIC, is engaged in the research and development of advanced electro-optical devices and systems, advanced hyperspectral algorithms, and software to support environmental and underwater applications. **Science and Technology International (STI)**, based in downtown Honolulu, focuses on the ability to acquire and process spectral information about objects, using visible to near-infrared and thermal hyperspectral imaging systems, dual-mode fluorescence imaging, grazing LIDA, and other sensor technologies to facilitate data collection and system integration, image and statistical analysis, and complementary products and services. **Geo InSight International Inc.**, another MIC tenant, specializes in geographic information solutions and products for defense, government and industry, combining leading-edge data collection and visualization technologies with industry-standard software and systems to develop cost-efficient, flexible, and powerful GIS desktop, enterprise, and web-based applications.



Pacific Marine, through its subsidiary **Navatek**, is a nationally recognized leader in the design of advanced ship hull forms for the **U.S. Navy’s Office of Naval Research**. The company’s patented **MIDFOIL hull design** emerged from a decade of research on **SWATH, hydrofoil, and underwater lifting body hull technologies**. The MIDFOIL hull form offers superior stability in rough seas; increased payload; reduced fuel costs; and permits higher speeds without an increase in installed horsepower. This “dual use” technology has commercial applications as well, including as a fast passenger or car ferry. The company is looking at using the technology in Hawaii for an inter-island ferry. **MHPCC** supports Navatek’s computational fluid dynamics (CFD) work used to design and improve the company’s cutting-edge MIDFOIL technology.

- ◆ **Pacific Disaster Center (PDC):** The PDC is a federally supported information processing center designed to **develop and provide value-added information to assist federal, state, local, and regional emergency managers with disaster mitigation, preparation, response and recovery within the Pacific region.** PDC brings information innovation to the disaster management community by linking scientific understanding, open-source data, and web-based geospatial technologies to support disaster reduction. PDC is being developed as an organizational and technological model for global, national, and local disaster management initiatives.

Based in Hawaii, PDC has resources located on the islands of Maui and Oahu. The main PDC facility is situated in the **Maui Research & Technology Park.** Smaller satellite facilities are in Diamond Head Crater with the **Hawaii State Civil Defense Emergency Operating Center** and Fort Shafter with the **U.S. Army Corps of Engineers, the Federal Emergency Management Agency (FEMA), the U.S. Navy's Pacific Fleet (PACFLT),** and other federal entities engaged in emergency management in the Pacific.

Many federal civil and defense department agencies have become involved in PDC development. Federal participants have included (but are not limited to) the **National Oceanic and Atmospheric Administration, the National Weather Service, the U.S. Geological Survey, the National Aeronautics and Space Administration (NASA), FEMA, and the U.S. Department of Defense.** In FY 1999, the NASA Solid Earth and Natural Hazards (SENH) program executed a joint DoD-NASA program for research and development of **modeling and simulation (M&S) applications for consequence assessment of natural and man-made hazards.** NASA awarded and is now managing 15 projects consisting of contracts, grants, and cooperative research agreements to develop M&S applications for operational integration into the PDC.

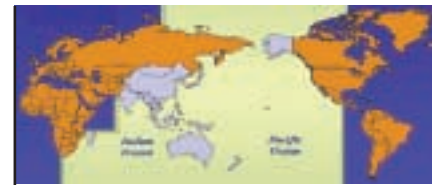
Other dynamic dual-use areas under development at the University of Hawaii and at several Hawaii-based companies include **intelligent underwater vehicles** to support cable streaming, mine hunting, and munitions retrieval projects; the manufacturing of **composite materials** for use in spacecraft, space structures, and electric vehicles; **microelectro-mechanical**

systems for use in weapons and control guidance, navigation, mass data storage, identification systems, and aircraft operations; **wave-length division multiplexed networks** to support telecommunications and Internet infrastructures; and **micro/millimeter wave communication systems** to enhance automotive radar, collision-avoidance systems, and landing and navigational aids for aircraft and ships.

Courtesy KEDB



The **West Kauai Technology & Visitor Center,** which initially opened in April, 1999, is undergoing a \$3.9 million renovation to support operations for an expanded host of tenants including **Digital System Resources, the Office of Naval Research, SAIC, Lockheed Martin, Northrop Grumman, Boeing, MIT Lincoln Labs, the Sensor Integration Center, and Science & Technology International.** These companies will bring a strong focus on dual-use technology as they support the ongoing operations of the **Pacific Missile Range Facility.**



Courtesy PDC

The area of interest of the **Pacific Disaster Center (PDC)** initially included Hawaii, Alaska, and the Pacific insular States of Guam, American Samoa, Marshall Islands, Northern Marianas, Palau, and Micronesia. In April 1998, Public Law 105-174 expanded the area of interest of the PDC to match the area of responsibility of the Commander in Chief, Pacific Command. This expanded geographical responsibility (shaded in blue) currently extends westward from the West coast of the continental United States, to the East coast of Africa, thereby including almost all of the Pacific Ocean and East Asia.

DISASTER MANAGEMENT

Examples of PDC Products - The data resources and computing power available through the PDC enable emergency managers to access a **broad range of information regarding both natural and man-made disasters.** Pictured above, clockwise from left, are: GOES-9 Visible Imagery of a hurricane; annotated imagery showing the extent of the storm surge; Makaha Valley surface analysis; multispectral flood imagery; a water restrictions map of Hawaii County; a map of Oahu-North Shore precipitation totals; potential coastal storm surge and flood hazards areas; and a hurricane watch and warning situation map.

Courtesy PDC

ENVIRONMENT & RESOURCE MANAGEMENT

Promoting Responsible Development through Sustainable Technologies

Courtesy HINHP



The map above shows rare and endangered species locations overlaid on the remaining native natural communities in West Oahu as documented by the Hawaii Natural Heritage Program's Natural Diversity Database and GIS. The HINHP database and GIS is the largest of its kind in Hawaii and contains information such as numbers of individuals seen, date last observed, habitat conditions, threats, and other details relevant to conservation. The Hawaiian tree snail (*Achatinella mustelina*) is an endangered species found only on Oahu. It spends most of its life on native trees and/or bushes such as the O'hia, where it feeds on fungi which it scrapes from the surfaces of the leaves.

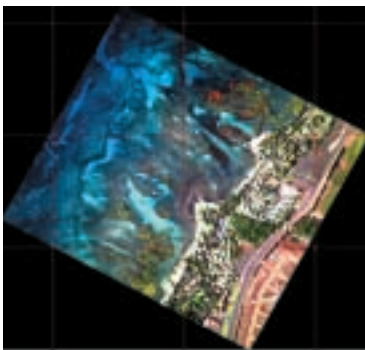
The critical links between Hawaii's fragile island ecosystem and its economy have encouraged numerous innovations in environmental technology and energy efficiency. Private firms operate highly efficient combined-cycle oil-fired generators as well as a state-of-the-technology 180MW coal-fired power generator employing atmospheric fluidized bed combustion for extremely clean electricity production. The state is also a leader in the use of highly efficient electrotechnologies for lighting, cooling, and other demand-side applications.

The Hawaii Natural Heritage Program (HINHP) at the University of Hawaii works to protect the environment for future generations by surveying conservation zones for areas of biological significance and monitoring threats to ecosystem health such as alien species encroachment. HINHP staff currently maintains the Natural Diversity Database – the most comprehensive spatial database inventory of rare and endangered, plants, animals, and ecosystems in Hawaii. HINHP uses geographic information systems (GIS), global positioning systems (GPS), and remote sensing to provide invaluable biological information on the distribution and abundance of these species to state, federal, and private organizations. As part of the Center for Conservation Research and Training (CCRT), HINHP has expanded its mission to include training and mentoring programs that strive to integrate scientific research and technology

with applied natural resource management to enhance problem solving and decision-making. This Hawaii-based program is working to spur the development of GIS-based biodiversity databases in other regions and to serve as a major research and training center for natural resource managers from the Asia-Pacific Region.

MANAGING NATURAL RESOURCES

Courtesy TerraSystems, Inc.



This view of the coastline of West Maui, a digital map produced with TerraSystems' TS-1 multi-spectral camera, highlights coastal areas (blue) infested with the obnoxious red algae, hypnea (coded red), and benign green algae (coded green and yellow). TerraSystems, Inc., a Hawaii-based technology corporation, provides airborne and spaceborne remote sensing imagery and imagery products (primarily from high-resolution panchromatic, multispectral, hyperspectral and imaging radar sensors) for environmental monitoring and engineering, coastal assessment, and land use resource management.

Among the most limiting commodities of island ecosystems are their water resources. Protection of watershed ecosystems to sustain water quality and quantity is critical for economic development. The fringing coral reef ecosystem is also an important component of an island's economic base. Fisheries, tourism, recreation, and other marine activities are dependent on the health of the coral reef ecosystem. Impact from red soil erosion and other human activities such as agriculture, and the construction of roads, dams, and other structures, can result in soil runoff into coral reefs. GIS analyses of hydrological features will be increasingly important for protecting both watersheds and marine ecosystems.



Pictured above is a pseudo-color 3-D rendering of Kaneohe Marine Corps Base on Oahu created for watershed management (watershed demarcated in red). This image was produced by Geo InSight International, Inc. – a consulting firm specializing in GIS and related technologies, including CAD, DGPS, remote sensing/ image processing, digital orthophotography, and multimedia database management. The company provides comprehensive planning, design, development, and integration services; custom programming; GIS training and on-site technical assistance. Custom programs enhance the utility and productivity of AutoCAD, ARC/INFO, ArcView, ERDAS, and Intergraph/MicroStation for environmental resource management, utility management, and defense and emergency response planning.

Courtesy Geo InSight International, Inc.

Growing concern about climate change and global warming due to anthropogenic greenhouse gas emissions has led to increased interest in ways to reduce or offset those emissions. **Forestry in Hawaii** offers some profitable opportunities for development or acquisition of such offsets.

The Kyoto Protocol committed nations to place legally binding limits on their emissions of greenhouse gases (“GHG”). A central feature of the protocol is a set of binding emissions targets for developed nations. The protocol enabled two forms of exchange – trading of assigned emissions amounts, and project-based emissions reduction credit trading – to spur nations to shift to greenhouse-friendly development. The protocol also facilitates application of these incentive systems to the conservation, management, and regeneration of forests that sequester CO₂ – the principal greenhouse gas.

Hawaii has a unique combination of attributes and a window of opportunity to establish **Carbon Offset Forestry** (COF) initiatives. Successful COF projects can be designed in Hawaii that meet all identified international criteria. Hawaii’s existing native and naturalized forests, which have been under active management since the turn of the century, already provide a large carbon sink. In addition, thousands of acres of agricultural lands are now vacant after over 100 years of sugar production.

Although the protocol for carbon credits has not been finalized, many companies are already investing in COF projects. Some projects undertaken have had public relations as well as carbon sequestration benefits, but all have offered valuable experiences that will affect the future of other larger scale COF projects. In addition, credits may be transferred or sold, offering a promising source of income for the industry.

Private industry has recognized Hawaii’s advantages for forest investment (political stability; ideal growing conditions; skilled workers with relatively easy transition of skills; machinery from the sugar industry; excellent roads, ports, and telecommunications; research and development institutions; and attractive living conditions), and has begun to make major investments in forest plantations. Sizable investments in **carbon sequestration** can be attracted from outside Hawaii by partnering with the State and private landowners to mitigate global warming and create a sustainable local forestry industry, with value to be derived from a system of tradeable international emission credits.

Research and development efforts currently underway in Hawaii have the potential to provide alternative energy, as well as to contribute to greenhouse gas emissions reductions. Researchers from the U.S., Japan, Norway, Canada and Australia plan to test the feasibility of **deep ocean sequestration of CO₂** via discharge from submerged pipelines. Hawaii researchers have previously proposed and published papers on a process to reduce CO₂ emissions from power plants by precombustion reforming of fuel and deep ocean discharge of CO₂ from fossil fuel. The process involves reforming a hydrocarbon fuel into a mixture of hydrogen to be used for power generation, while the liquefied CO₂ is discharged into the deep ocean. In the future, such measures may be among those necessary to reduce CO₂ emissions and their impact on global climate.

Hawaii’s private sector is working to accelerate and commercialize **key sustainable technologies** that will support the Earth’s burgeoning population while reducing environmental pollution. These efforts have not only received nationwide commendation, but have also contributed to the State’s programs in international technical assistance and service sector exports, particularly in the Asia-Pacific region. Several companies in Hawaii are finding **creative ways to utilize waste products**, which include converting used plastics to manufacture plastic lumber; greenwaste to produce soil amendment products; recycled cellulose for hydromulch

OPPORTUNITIES IN FORESTRY



Courtesy Dr. Michael J. Antal

Charcoal has been made in virtually the same way for 6000 years. The process is long, causes severe air pollution, and produces low yields. An innovative technique developed by **Dr. Michael J. Antal, Jr.**, Coral Industries Distinguished Professor of Renewable Energy Resources at the University of Hawaii, can significantly decrease production time to an hour or less, thereby **reducing smoke and other pollution while doubling yields**. This enhanced efficiency could also help **slow deforestation and reduce greenhouse gas emissions** in many developing nations that use large amounts of charcoal. Pictured above is a **High-Yield Charcoal Pilot Plant** in operation at UH.

MANAGING CO₂ AND WASTE PRODUCTS



Courtesy HNEI

Chambers at the **Hawaii Natural Energy Institute (HNEI)** that simulate the ocean depths are used to **test the potential of sequestering carbon dioxide**, a major greenhouse gas, in deep ocean waters.

PROMOTING ENERGY EFFICIENCY

Courtesy ERTD/DBEDT



The groundbreaking ceremony for the **Hawaii Energy Efficient Model Demonstration Home in Waianae Valley** on Oahu, November 6, 2000. This is the first packaged home with energy-efficient features including a solar water heater, radiant barrier, and natural ventilation. These items will help keep the house comfortable for living year-round without the need for air conditioning. The people in the photo include (L to R): Peter Dreyfuss, Deputy Chief of Staff, Energy Efficiency and Renewable Energy, U.S. Department of Energy; Raynard C. Soon, Chairman, Hawaiian Homes Commission; Chuck Ehrhorn, AIA, President, Honolulu Chapter, American Institute of Architects; Maurice H. Kaya, Program Administrator, DBEDT Energy, Resources & Technology Division; Audrey Hidano, President, Building Industry Association of Hawaii; Randy Lau, Designer Built Systems; Jackie Mahi Erickson, Vice President, Hawaiian Electric Company, Inc.; Terris H. Inglett, President and Chief Operating Officer, Honsador Lumber Corporation.

and insulation; used paper for oil change boxes; and a broad range of functional and beautiful items from recycled glass. Some waste products are also used for energy and fuels production (see also *Renewable Energy*).

The U.S. Army in Hawaii is proposing to conduct a **phytoremediation demonstration project** at Makua Military Reservation on Oahu, using soils from the Open Burn/Detonation Unit. Phytoremediation utilizes plants to help extract and reduce undesirable chemicals that may be detrimental to the land where they are being deployed. The objectives of this project are to (1) demonstrate the effectiveness of plants, unique to the Asia-Pacific region, to bioaccumulate and biodegrade contamination; (2) assist with the transfer of this technology to other areas in the Asia-Pacific region that require similar applications; and (3) expand education and outreach by helping to retrain agricultural employees in agriculturally-based remediation programs through the hands-on applications involved with this project.

A *Directory of Environmental Businesses in Hawaii* (www.state.hi.us/dbedt/ert/chc/00envdir.html) lists major environmental businesses, organizations, and government agencies in the State of Hawaii, including consultants, engineers, physicians, and researchers; recycling, remanufacturing, cleaning, repair, and waste disposal companies; energy, parts, supplies, and equipment; and wholesalers, retailers, and exporters.

Over the years, the State of Hawaii has demonstrated considerable leadership in promoting **energy efficiency programs**. For example, the state has successfully attracted federal funding to initiate a number of innovative programs developing **guidelines for efficient residences**, assisting local builders to incorporate these guidelines, promulgating the **Model Energy Code** for commercial buildings, and evaluating the latest electro-technologies for Cooling Climates. The technical information and tools developed from these programs provide excellent technical assistance services and products for export.

Hawaii has created a unique statewide partnership to promote energy-efficient buildings under the **Rebuild Hawaii Consortium** that facilitates cooperation and technical exchange among local, state, and federal agencies, private energy businesses and professional organizations. The State of Hawaii was recognized by the U.S. Department of Energy for its outstanding achievements through the Rebuild Hawaii program, and received the **Rebuild America Award for Energy Excellence in State Government**, the **Rebuild America State Representative of the Year**, and the **Rebuild America Award for Energy Excellence in Commercial Buildings**. The experience and expertise of initiating and expanding public/private partnerships and the examples of successful, efficient building technologies are highlights which can be shared for export.

In co-sponsorship with eleven industry, government, and community organizations, the State of Hawaii staged a highly successful **Energy Efficiency Policy Symposium** to discuss cost-effective alternatives to increase energy efficiency and sustainability. In addition to a presentation of alternative state energy policies, emphasis was given to the significance of diminishing reserves of fossil fuel, the need for promoting energy-efficiency, and the importance of using renewable resource and technologies. Speakers discussed their individual state approaches to help attain these goals. Over 140 attendees participated in discussions focusing on energy policies and practices. A number of distinguished speakers also joined this event, including, a leading petroleum engineer, two nationally renowned economists, and representatives from the U.S. Department of Energy, California, Arizona, North Carolina, and the National Conference of State Legislatures. Local speakers represented the local energy industry, the electric utilities, low-income housing programs, and a nonprofit school. Papers presented at this Symposium are available at www.state.hi.us/dbedt/ert/symposium.

The state is conducting a pilot assessment of state and county lands which qualify as brownfields: lands which are perceived to be contaminated. The purpose of the assessment is to identify a select number of sites for testing and cleanup. The economic and environmental benefits will be the availability of previously unused lands opened for economic development or open space. The resulting procedural and technical information, as well as the environmental cleanup expertise and practices, can provide technical assistance and export opportunities.

In early 1997, Governor Benjamin Cayetano proposed to then Philippine President Fidel Ramos that the Republic of the Philippines and Hawaii collaborate on developing **biomass-to-energy and biowaste management** projects. As a result, in May 1997, a *Memorandum of Understanding (MOU)* was implemented to initiate a cooperative assessment of Philippine biomass-to-energy potential, with at least two commercial bio-energy projects included as case studies.

In concert with this MOU, a **strategic technology market assessment and development program** has been established by DBEDT to facilitate increased exports of U.S. energy, environmental, and other sustainable technologies and related services into Asia/Pacific markets. Sustainable technology, especially in the areas of energy and environmental technologies, will also help to reduce greenhouse gas emissions and mitigate global warming. Bolstered by national support from the U.S. Department of Energy and the Council of State Governments, the program seeks to match commercial applications of sustainable technologies and related services with targeted demand in the Asia-Pacific region.

With full intergovernmental agreement and private industry participation, Hawaii and the Philippines have embarked on a **long-range collaborative program which seeks to increase energy conservation, reduce greenhouse gas emissions, and develop new energy-efficient high technology industries**. The principal components of the program, with potential applicability to Hainan Province, China, and countries of the Indo-China Peninsula, are to:

1. Introduce advanced Hawaii and U.S. energy efficiency technologies and policies to the Philippines.
2. Support expansion of the Philippines renewable energy industry, including identification of biomass-to-energy opportunities and assessment of the biomass-electricity potential of representative sugar mills.
3. Promote environmentally sound energy efficiency and renewable energy policies and practices.
4. Introduce Hawaii and U.S. energy service companies to business development and partnering opportunities in the Philippines.
5. Provide policy advisory support on the refinement and enforcement of Philippine energy codes and building standards.
6. Provide policy and technical assistance on designing and implementing utility demand-side management programs, as well as on energy efficiency performance contracting.

The **Hawaii Natural Energy Institute (HNEI)** at the University of Hawaii is conducting an **assessment of bioresidue resources in the Philippines** with the goal of utilizing these resources to generate clean, renewable energy cost effectively. The major components of this effort are **case study investigations of power generation at two sugar mills** using sugarcane bagasse. The study is also identifying opportunities for existing and emerging biomass-electricity technologies and technical services (see also *Renewable Energy*).

INTERNATIONAL COLLABORATION



The State's efforts to transfer energy technology and improve environmental protection in the Philippines is paving the way for Hawaii energy and environmental firms to facilitate the **reduction of greenhouse gas emissions** that contribute to global climate change, as well as to develop new business opportunities for Hawaii. Pictured above are Hawaii representatives leading a Workshop on Energy Efficiency Policies and Technologies in Manila.

Courtesy ERTD/DBEDT

HEALTH CARE & MEDICAL TECHNOLOGY

Pioneering Research and Clinical Applications

Courtesy, Dick Teshima/DMT-JABSOM



The John A. Burns School of Medicine's Division of Medical Technology trains medical technologists, or clinical laboratory scientists, to perform laboratory tests and interpret data on blood, urine and other specimens to help diagnose and treat diseases, and to monitor health status. The ability to distinguish clinically significant morphologic changes from normal variations requires microscopic analysis. In the picture above, a UH medical student uses a microscope attached to a CCD camera to record and study medical images in fine detail.

UNIVERSITY TRAINING & RESEARCH

Hawaii is nationally recognized as “the Healthcare State.” Over 85% of its citizens are insured and have their choice of several health care plans that compete to provide high-quality personalized care. Access to specialty expertise is readily available, employing the most advanced healthcare concepts and technologies.

Hawaii's healthcare providers come from ethnically diverse backgrounds, with training from a broad range of local and mainland institutions, and support the culturally sensitive healthcare that our multicultural population requires. With its mild subtropical climate, multiple tourism attractions, and state-of-the-art medical facilities, Hawaii also provides an ideal healthcare venue for patients from around the Asia-Pacific region, as well as an attractive “R & R” ambience for their families.

Under the aegis of a newly-recruited dean from Yale University and with the prospect of an expansive site along Honolulu's waterfront, the University of Hawaii's **John A. Burns School of Medicine (JABSOM)** offers vast potential for education, training, research, and town-gown interaction. Dean Edwin C. Cadman has set forth his goal to “establish JABSOM as a top flight educational institution as well as a leader in biomedical science research [and to] build a new learning environment that incorporates technologies on which our physicians of the future will rely.”

Medical Education for physicians, biomedical scientists, and allied health workers in Hawaii and around the Pacific is a core component of JABSOM's mission. The school is one of only a handful of schools in the nation to convert its curriculum to a “problem-based learning” format adapted from McMaster University in Canada. Through this **MD Program**, students are trained to think critically, to evaluate new information and research data, and apply their new knowledge to the problem at hand. Special features of the program include an emphasis on primary care medicine and cross-cultural psychiatry; clinical training in community hospitals and primary care clinics (by medical school faculty); interdisciplinary training in community medicine together with students of public health, nursing, and social work; and opportunities for preceptorships in rural areas of the Hawaiian Islands and other areas of the Pacific Basin. This novel approach marks a profound reshaping of the entire learning process – one much better suited to training the high-quality physicians of the future.

Advanced Medical and Biomedical Research constitutes another core component of the JABSOM's mission. Beginning as an outgrowth of the University's **Pacific Biomedical Research Center**, JABSOM has since become a major research center in the pathology and etiology of disease. It has received international recognition for pioneering work in human fertility, human heredity, comparative genetics, evolution theory, infectious disease, pharmacology, and cross-cultural psychiatry, among other fields.

Last year, Dr. Ryuzo Yanagimachi, a JABSOM faculty member, rocked the scientific community with the announcement that his research team had successfully **cloned laboratory mice**. His distinctive cloning technology, dubbed the “**Honolulu Technique**,” provides scientists with a new and valuable tool for researching the molecular processes involved in embryo formation, cell differentiation, aging and disease. It is likely to have major applications in farm animal production, the pharmaceutical industry and in transplantation medicine (see also *Biotechnology*).

Another trailblazing JABSOM researcher, Dr. Clayton Chong, is lead investigator for a national clinical trial at St. Francis Medical Center exploring **gene therapy**. This new form of medical treatment could offer ways to ameliorate and even cure diseases. For example, gene-therapy protocols are exploring new treatments for cancer in which genes that kill tumor cells are being introduced into cancer patients through clinical trials.

In the field of **Tropical Medicine**, JABSOM serves as a resource for infectious disease research, particularly in relation to illnesses common to Pacific Basin and Pacific Rim countries. In fact, JABSOM has clinical responsibilities for patients with the broadest range of infectious diseases of any U.S. medical school. JABSOM's **Human Malaria Research Program**, run through Leahi Hospital, is actively engaged in the **development of a malaria vaccine**, and has developed collaborations with other prestigious research teams including the Institute Pasteur in Paris and Tokyo's Daiichi Pharmaceutica, as well as with field site scientists in Papua New Guinea, the Philippines, and Colombia. Dr. Sandra Chang and her team of researchers in the Department of Tropical Medicine and Medical Microbiology have developed an **experimental vaccine using recombinant DNA technology** that has proven effective in tests with monkeys. UH is patenting the vaccine and working with the World Health Organization and a European pharmaceutical company to produce sufficient quantities of the vaccine for human clinical trials that could begin in 2002.

JABSOM's program in **Geriatric Medicine** has achieved national and international prominence and attracted significant extramural funding in support of its educational and research activities. The Program's **Pacific Islands Geriatric Education Center** is designed to help alleviate the shortage of health professionals in Geriatrics. Its areas of focus include developing new clinical geriatric services, improving the geriatric curriculum in health professions schools and providing geriatric training to health professionals currently working with older people. The **John A. Hartford Foundation Center of Excellence in Geriatrics**, a joint effort of the Foundation, the **University of Hawaii Geriatric Medicine Program**, and **Kuakini Medical Center**, is the main teaching hospital for the JABSOM Geriatric Medicine Program, with the goal of attracting and preparing outstanding physicians for careers in geriatrics.

The year round popularity of SCUBA diving in Hawaii mandated the need for a facility that could provide definitive emergency care for divers who suffer from Decompression Illness such as "the bends" and gas embolism. JABSOM's **Hyperbaric Treatment Center (HTC)** also provides adjunctive supportive hyperbaric oxygen (HBO) for patients suffering from non-healing wound, radiation damage, and other medical conditions that benefit from the delivery of extremely high levels of oxygen. First opened in 1983, HTC is one of the few research centers in the world exclusively dedicated to hyperbaric medicine. Their updated, state-of-the-art facility, located at Kuakini Medical Center, was completed in 1995.

JABSOM also has made a major commitment to involving its students in the community it serves through several major programs, including the "**Community Partnerships with Health Professions Education**" initiative funded by a competitive \$6 million grant from the Kellogg Foundation. This innovative program has led to an association between the University of Hawaii's Schools of Medicine, Nursing, Public Health and Social Work, and several community health centers throughout the State to develop and maintain a dynamic, community-based and integrated system of medical care, education and research.



Courtesy JABSOM

The 15,000 square foot **Institute for Biogenesis Research** was dedicated in September, 2000, at the University of Hawaii's John A. Burns School of Medicine. The institute represents a joining of state, university and private funding to create a world-class research facility. The \$4.9 million state-of-the-art building was created to help take the School of Medicine's ground-breaking research to the next level, as well as to attract top researchers to the University.



Courtesy Dr. Robert Overlock - HTC/UH

The **Hyperbaric Treatment Center** at Kuakini

Looking to the Future:

Dean Edwin Cadman is working to ensure that JABSOM will remain "Hawaii's leader in the study and evaluation of human health and disease – not only in the health of populations, but also in the basic scientific investigation of the molecular biology of disease." In concert with this vision, JABSOM is building upon its current programs to pursue innovative initiatives that will:



Courtesy: JABSOM

- ◆ Use computer technology and the resources of Maui's High Performance Computing Center (MHPCC – see also *Defense and Dual-Use Technology* and *Information Technology*) to develop a center that will have the capability to simulate life-threatening and pre-surgery conditions – a facility destined to become one of the nation's leading centers for training and credentialing physicians.
- ◆ Take advantage of Hawaii's unique mid-Pacific location to pioneer the study of life-threatening infectious diseases emerging in the Asia-Pacific region.
- ◆ Enable Hawaii to grow as a nationally-recognized leader for the education, study and evaluation of complementary and alternative medicine.
- ◆ Facilitate development of a vaccine for HIV, partnering with Asian countries where the AIDS epidemic is on the rise.
- ◆ Provide a platform for studies involving disease prevention using our understanding of the human genome.
- ◆ Focus on neurogenerative disorders, complementing efforts underway on the biology of neurological disorders in AIDS and the biology of cognition.
- ◆ Promote research conducted at the medical school's new Institute for Biogenesis Research on cloning, embryo development, transgenesis, germ cell biology, and fertilization analysis and assisted reproduction.

TELEMEDICINE AND TELEHEALTH

Telemedicine – the use of advanced telecommunications technologies to exchange health information and provide health care services across geographic, time, social and cultural barriers (as defined by Jim Reid in his *Handbook on Telemedicine*) – is becoming more feasible and affordable with reductions in telecommunications costs and innovations such as digital technology, fiber-optics, Internet technologies and protocols, and rapid advances in computer science and capabilities. Hawaii has long been investing in telecommunications and telehealth technologies. Both State government and the private sector in Hawaii anticipated the digital revolution and championed the development of the infrastructure necessary to meet the state's telecommunications needs – including networks with the bandwidth, or carrying capacity, for high volume data transfers.

Telemedicine and telehealth operations have grown in Hawaii as in the rest of the U.S. The Department of Defense, through the **Tripler Army Medical Center** and the **AKAMAI Project**, is a renowned pioneer in telemedicine, both nationally and internationally. **Tele-radiology** in Hawaii has become a mature application with proven utility. All the major community hospitals and health care systems have been investigating and investing in telemedicine capabilities. The **Hawaii Health Systems Corporation (HHSC)**, an association of State Hospitals, regularly utilizes telemedicine technologies. HHSC and community health centers have been the recipients of grants from the **Harry and Jeannette Weinberg Foundation** for telemedicine equipment. Divisions of the University of Hawaii, such as the **School of Nursing at Manoa** and the

UH Community College System, have been using telemedicine technologies for medical education and patient care. Pilot studies using low bandwidth video-phones are currently underway. Other health organizations such as third party payers, capitated health plans and medical service organizations are looking to telemedicine to improve and enhance services.

JABSOM is one of 10 medical schools across the country involved in telemedicine and telehealth education and applications. Undergraduate, graduate, post graduate and continuing medical educational programs already use multiple modalities of telemedicine including store and forward systems, as well as real time, full motion, multipoint video teleconferencing.

The **UH Telemedicine Project** – a JABSOM research group – is currently developing a multimedia telemedicine curriculum for the Department of Defense that will assist health care providers in the use of telemedicine technologies to deliver health care and medical education over distance. The Project is establishing a clinical telemedicine network as a test bed to allow University students, physicians in training, faculty and community primary care physicians, medical sub-specialists, and other health care providers to learn to use telemedicine both in patient care and medical education. The **State of Hawaii Telehealth Access Network (STAN)** and **UH/ Information and Technology Service (ITS)** are providing connections that allow high speed data transfer for video teleconferencing,

as well as store and forward access to the University of Hawaii and Community College System, Waianae Coast Comprehensive Health Center, The Queen Emma Clinics, and the Kalihi Palama Community Health Center. Similar connections will be extended to HHSC, the Veterans Administration Regional Medical Center, private sector health care organizations and via satellite to areas of the Pacific.

Another model demonstration project representing a telehealth collaboration between JABSOM and the University of New Mexico Medical School, **Project TOUCH** (Telehealth Outreach for Unified Community Health) is part of a multi-year strategy to improve the quality of health care service and education in remote multicultural areas within both states. Utilizing advanced information systems and high performance computing, and in collaboration with rural hospitals and training sites, the medical schools are enhancing and deploying their existing problem-based learning curricula to support training of students and health care providers. The current curriculum is focusing on traumatic brain injuries, and uses the **Maui High Performance Computing Center's** massively parallel processing computer to provide virtual reality models, enhanced 3-D images, and computer simulations for the project. "We plan to be of service to the university, the school of medicine, the healthcare community, and the community at large," notes TOUCH project director Dr. Stanley Saiki. "Our goal is to help these groups utilize the advanced technologies in computing and telecommunications in order to provide medical education and healthcare services over distance. Parallel computing gives us access to powerful machines that can create three-dimensional displays and virtual reality environments. It's a frontier offering revolutionary opportunities for learning."

A number of medical and research institutions in Hawaii are pioneering the forefront of telemedicine and telehealth. Supported by a \$550,000 grant from the Technology Opportunities Program of the U.S. Department of Commerce, the **Fetal Tele-Ultrasound Project** supports women with high-risk pregnancies through the **Fetal Diagnostic Center (FDC)** at **Kapiolani Medical Center (KMC)**. Radiologists, obstetricians and primary care providers refer high-risk pregnancies to the location of the nearest ultrasound machine in the community where the patient lives. The machines are electronically linked to the FDC, where specialists are able to remotely observe the medical condition of each patient. This system increases the accessibility of women with high-risk pregnancies to specialty healthcare services, and reduces the driving and flying time of both pregnant patients and physicians in providing optimal diagnostic care. Through this tele-ultrasound service, FDC can provide specialty care and advice 24 hours per day, 7 days per week.

Another catalyst enhancing medical services in Hawaii is **Dr. Earl Bakken**, the inventor of the pacemaker. Since retiring in Hawaii, Dr. Bakken has become a leading figure in a movement to transform the "Big Island" of Hawaii into the "Healing Island." The "healing concept" is a holistic approach which embodies the curative properties of Hawaii's clean air, salt water, sun, earth, spirituality, and aloha, complemented by state-of-the-art medical equipment. This **new healthcare delivery model is especially suited for chronic pain, cosmetic and reconstructive surgery, stroke rehabilitation, dermatology, electrical stimulation procedures, sports injuries, assisted living and hospice care.** Dr. Bakken is also the co-founder of **Medtronic** – the **world's leading medical technology company** – providing a wide range of products for physicians to solve the most challenging medical problems. Medtronic, which generates annual revenues of over \$5 billion, does business in 120 countries, and has a workforce of 25,000 employees.



Courtesy SSRI/UH

The **State Telemedicine Access Network (STAN)** was established in 1997 as a partnership among the **Hawaii Health Systems Corporation (HHSC)**, the **High Technology Development Corporation (HTDC)**, the **Pan-Pacific Education and Communication Experiments by Satellite (PEACESAT)**, and the **Telecommunications and Information Policy Group (TIP-G)** of the **Social Science Research Institute of Hawaii**. This public-private network enables health care providers, educational institutions, and health and economic development government agencies in the Asia-Pacific Region to interconnect clinical, financial, and management information systems; clinical telemedicine systems and applications; continuing health and medical education and training; and community and patient information services. It achieves client connectivity through fiber optics, digital microwave, high-bit rate copper, Integrated Services Digital Networking (ISDN), and satellite telecommunication links.



Courtesy KMC

Pictured above is the **Kapiolani Medical Center (KMC) Fetal Tele-Ultrasound Machine**. The monitor shows the fetus' image in the mother's womb to the attending physician. The unit to the left is the **Tandberg Health Care System III**, which enables the hospital to retrofit the regular ultrasound unit to become a "tele-ultrasound" unit. A wide angle camera is mounted on top of the monitor, where there is also a unidirectional microphone which facilitates freedom of conversation among patient, physician, and technician at the remote satellite site with the perinatologist at the **Fetal Diagnostic Center** on Oahu.



Dr. Jorge G. Camara at **St. Francis Medical Center** in Honolulu uses **video teleconsultation** to help guide another doctor performing eye surgery on a patient at Hilo Medical Center on the island of Hawaii. The **first such teleconsultation of its kind, performed by St. Francis to support orbital eye socket surgery** in February of 1999, was covered nationally by NBC News and CNN.

St. Francis Medical Center (SFMC) on Oahu is pioneering the use of **video teleconsultation** to support teleconsultation during clinical procedures in remote locations. In February, 1999, Dr. Jorge Camara, based at St. Francis in Honolulu, assisted ophthalmologist Susan Senft at North Hawaii Community Hospital on the island of Hawaii in removing a tumor in the orbital eye socket of a 16-year-old girl. This was **the first time in the world that telemedicine technology was used in the removal of an eye tumor**. The operation took 50 minutes; and only a few hours after the operation, the teenage patient was resting comfortably at home. The project was made possible through sophisticated videoconferencing equipment donated by the **Harry and Jeanette Weinberg Foundation**. GTE Hawaiian Tel (now **Verizon Hawaii**) was St. Francis Medical Center's provider for the network and equipment for this telemedicine procedure. As one of the vendors for the telemedicine network, Verizon Hawaii will help complete the project's goal of connecting six islands and 28 hospitals and clinics.



A **Gamma Knife Center of the Pacific** has been established at **St. Francis Medical Center** in Honolulu to train neurosurgeons and market its services to patients across the Pacific. Despite the title, the Gamma Knife is not a knife at all, but an instrument which converges 201 beams of cobalt-60 radiation on trouble spots inside the brain. The technology doesn't eliminate the need for conventional brain surgery, or conventional radiation or chemotherapy, but can be used in select situations where it's the best treatment choice – for example, in the case of deep-seated or spread-out tumors. Pictured above, Dr. Maurice Nicholson, Medical Director of the Gamma Knife Center of the Pacific, and Dawn Wahinekapu demonstrate the device.

St. Francis is also home to the **Renal Institute of the Pacific**, the largest hospital-based renal dialysis program in the nation. It runs the **Transplant Institute of the Pacific**, making St. Francis the only hospital in Hawaii to perform heart, kidney, bone marrow, liver and kidney/pancreas transplants. At the **Gamma Knife Center of the Pacific** (see sidebar), St. Francis neurosurgeons utilize state-of-the-art cobalt radiation technology to destroy brain lesions. The **St. Francis Heart Center** also pioneered the first laser procedure for treatment of heart disease in Hawaii. Called a TMR, or **transmyocardial revascularization**, this procedure involves the use of a high-energy, computer-synchronized carbon dioxide (CO₂) laser, called the **Heart Laser System**, to create channels through oxygen-deprived heart muscle (myocardium). Other specialty areas include cancer, liver, neurological and pain management services.

The **Pacific e-Health Innovation Center (P-eIC)**, located at **Tripler Army Medical Center (TAMC)** in Honolulu, was established by the Department of Defense to develop and exploit technologies that support a **virtual DoD Tri-Service electronic healthcare system throughout the Pacific region**. This support is being accomplished through prototyping, modeling, demonstrating, and validating emerging technologies for healthcare and clinical applications. In order to gain synergies in its efforts to further its goals, the P-eIC has established strong working alliances with a number of local, state and federal organizations, including the University of Hawaii, Harvard and Georgetown Universities, the Joslin Diabetes Center, the Office of Hawaiian Affairs, Alu-Like, the Economic Development Alliance of Hawaii, the Henry Ford Health Care System, Tripler and Walter Reed Army Medical Centers, the Department of Veterans Affairs, the Navy, Air Force, Coast Guard and Marines, and the Alaska Federal Healthcare Partnership.

The P-eIC has established an **agreement with the Economic Development Alliance of Hawaii to facilitate the transfer of DoD-developed telemedicine technologies to the private sector**. P-eIC has solicited proposals from commercial enterprises to partner with the DoD in executing leading-edge technology research, development, testing, and evaluation activities related to telemedicine. This cost sharing helps stimulate commercial firms by creating an incubator for developing innovative technology solutions to solve healthcare problems.

Researchers from Maui, Kauai, Hawaii, and P-eIC on Oahu are now collaborating on several **innovative E-health projects**. Funded by the DoD, these research projects are focused on improving medical treatment at remote military facilities and have short-term commercial applications that will benefit the public sector. One project, **RAMS-MT (Remote Access to Medical Specialists - Maui testbed)**, is managed and directed by **Trex Enterprises** located in the **Maui Research & Technology Center**. Continued collaboration with experts throughout Hawaii will lead to a “concept of operations” (CONOPS) for medical technology transfer from TAMC.

One notable function of RAMS will be to facilitate **monitoring of ICU critical care patients in remote locations**, allowing medical specialists to read EKG waveforms, blood oxygen levels, and blood pressure in near real time via a secure Internet connection. RAMS team members are also developing a “**decision support program**” designed to assist healthcare providers in interpreting patient monitoring information. This program could trigger an alarm when critical events occur, or provide treatment options based on information gleaned from clinical database information. **Trex Maui Sensors** is developing methods of capturing, transmitting and viewing digital radiographic images, which would be transmitted via the Internet to a secure viewer. Software being developed to recognize visual patterns and anomalies will assist physicians in interpreting these images.

The collaborative telemed project with TAMC is also exploring ways to improve existing e-health programs. Specialists at TAMC have formed an **Internet-based Tumor Board (ITB)** to review digital photographs of tumors while participating physicians from around the Pacific are connected to TAMC via a conference call to discuss the medical cases in real time. This procedure has resulted in a **reduced number of medical evacuations, better communication between primary care providers and specialists, and less disruption for seriously ill patients**. TAMC is also exploring methods to allow physicians to electronically post comments and suggestions for tumor board patients as their schedules allow (in “asynchronous” mode), allowing experts to collaborate without having to meet in real time.

Queen’s Medical Center (QMC) is pioneering the field of **broadband telemedicine for the home**. In the picture below, Dr. Dan Davis, Medical Director for Clinical Informatics at Queen’s, examines a digital photo of a skin rash sent through a **secure web-based telehealth messaging system**. New telemedicine projects at Queen’s include web-based home care, congestive heart failure management, continuing medical education, tumor board, a neurology movement disorder clinic, hospice, and state-of-the-art telehealth facilities at the new **Mabel Smyth Education Center**.



TREX Maui Sensors has developed a specialized package of **hardware required to remotely capture and transmit X-ray images**. The system is completely digital, and produces images (12 MB average in size) whose quality is equal to traditional film when viewed on high resolution TFT monitors. All components are FDA approved, and are being adapted for military field telemedicine.



The **Queen's Medical Center**, located in downtown Honolulu, Hawaii, is a private, non-profit acute medical care facility. It is the largest private hospital in Hawaii, offering a comprehensive range of primary and specialized care services. Licensed to operate with 526 acute care beds and 30 sub-acute beds, the medical center has more than 3,500 employees and 1,000 physicians on staff.

Courtesy TAMC

Courtesy QMC



The **Cancer Research Center of Hawaii** supports a broad range of activities to achieve its mission. On the left, a phlebotomist prepares human blood samples for long-term storage for future testing. The top picture illustrates a technician performing routine maintenance on a liquid chromatography mass spectrometry system. On the right, a researcher uses a fluorescence microscope to observe cell-to-cell communication.

Advanced medical research and technology in Hawaii is facilitating breakthroughs in both our understanding of the human body and the development of high-quality healthcare.

For example, the **Cancer Research Center of Hawaii (CRCH)**, one of 60 National Cancer Institute (NCI) - designated research facilities in the nation, unites top researchers, modern scientific equipment and technology to (1) identify and evaluate cancer risk factors; (2)

increase utilization of the best available approaches for early detection and treatment of cancer, and (3) enhance the quality of life of cancer patients and survivors.



The Positron Emission Tomography (PET) Scanner Hawaii is home to one of only a handful of PET scanners, brought to the islands through a cooperative agreement between **Hamamatsu Corporation** in Japan and **Queen's Medical Center**. PET is an unique imaging technology that allows physicians and researchers to map biochemical processes within the body in a non-invasive fashion. Unlike CT (computed tomography) and MRI (magnetic resonance imaging), which primarily shows the anatomical structures, **PET enables us to view body functions and provides diagnostic information as well as insight and understanding of disease.** The PET scanner is being used to assist in the diagnosis and evaluation of metastatic cancer, neurological disorders and brain metabolism. Medical laboratories in Hawaii are also developing drugs to complement PET capabilities and minimize the devastating effects of strokes

ADVANCED MEDICAL SCIENCE & TECHNOLOGY



Science & Technology International (STI) in Honolulu has designed an instrument for **Hyperspectral Diagnostic Imaging (HSDI)** that utilizes ultraviolet-excited spectral fluorescence and visual reflectance imaging techniques for the purpose of non-invasive disease diagnoses. The instrument has been designed to exhibit high sensitivity and specificity in tissue discrimination, while it also allows for a real-time, accurate and reliable assessment to be made. The function is to aid in the identification of malignant or pre-malignant lesions in topical cancer, including cervical and dermatological cancer. For cervical cancer, the goal is to replace the colposcopic examination.

The multifaceted Center supports a broad range of research activities and programs, including: an **Analytical Laboratory** for analyzing molecules from human body fluids and tissues from cells, food plants and from other matrices in support of clinical, epidemiologic and basic science studies; a **Genomics Laboratory** performing DNA/RNA isolation, custom genotyping, gene expression assays, library manipulation/construction, gene expression microarray fabrication and reading, and fluorescence *in situ* hybridization to support genetic and molecular biological analysis; a **Cancer Etiology Program** to identify factors, both exogenous and endogenous, that increase or decrease the risk of cancer, and to elucidate the molecular mechanisms that underlie the carcinogenic process; a **Prevention and Control Program** conducting basic and applied research in the behavioral, social, clinical, and population sciences; a **Natural Products Program** to foster collaborative research leading to the discovery and development of new drugs for the treatment of cancer, with emphasis on the systematic evaluation of the unique biota of the Indo-Pacific region as a source of molecular diversity; and finally, the **Hawaii Tumor Registry (HTR)**, which maintains a database of information on all cases of cancer diagnosed in the State of Hawaii and has proven invaluable in demonstrating ethnic variations in cancer incidence and survival.

Straub Clinic and Hospital in Honolulu has introduced many "medical firsts" to the islands, including **minimally-invasive techniques for open heart surgery and treatment of abdominal aortic aneurysms.** Straub was also among the first in Hawaii to use TPA – a clot dissolving drug that can greatly benefit many stroke patients by lessening the potentially devastating impact of a stroke and hastening the patient's recovery. In November of 2000, Straub opened a **Urogynecology Center** for women, the first of its kind in Hawaii, which is specializing in treating female incontinence, pelvic problems, recurrent urinary tract infections, and gynecological care for perimenopausal and postmenopausal women. The Center also specializes in treating abnormalities and pelvic organ prolapse.

Kuakini Health System has installed the most advanced **SONY PetaSite Mass Data Storage System** in Hawaii – part of \$2 million donation from **Sony Corporation**, **Sony Corporation of America** and **Sony Hawaii Company**. The PetaSite provides mass data storage utilizing a cost-effective tape format that holds 200 gigabytes of data per cassette, with an **overall capacity of 62 terabytes** (one terabyte is equal to 1 million megabytes). This technology will allow Kuakini to store data (text and video) and diagnostic images that would normally fill the shelves of many movable storage racks. Kuakini is using the PetaSite in conjunction with its PACS (Picture Archiving and Communications System), and in doing so has become **the fourth medical facility in the world to integrate a PetaSite with PACS for digital images**. Kuakini will also be **the first in the world to use the PetaSite to store multiple diagnostic modalities and multiple data types**, including digital imaging, video, and textual data for patient care, telemedicine applications and research. In addition to basic radiological images, the PetaSite will store nuclear medicine scans, ultrasound images, computerized echocardiography images, digital video imaging of angiography and cardiac catheterization lab procedures, pathology tissue images, training videos, billing records, patient’s medical records and research data. Because of the large quantity of storage space and long lifespan of the DTF-2 tapes, information can be held for up to 30 years without tape duplication.

The **Laboratory of Intelligent and Parallel Systems (LIPS)** at the University of Hawaii’s Department of Engineering is leading the charge in a variety of advanced medical technology areas. Dr. David Yun, laboratory director, and his team of research associates and assistants are pioneering a broad range of advanced medical technology applications, including:

- ◆ A patent on a new **3-D imaging process** which can render **virtual-reality “fly-throughs”** of everything from capillaries to canyons.
- ◆ A **laser-based system to detect breast cancer tumors** without the use of harmful X-rays.
- ◆ A **telemedicine network of satellites and supercomputers** to bring advanced cancer treatment planning to more remote regions of the planet.
- ◆ Small **wireless sensors to regularly monitor and analyze the blood sugar levels** of diabetics – a technology that could be used to help treat asthma, hypertension, and other chronic health conditions.

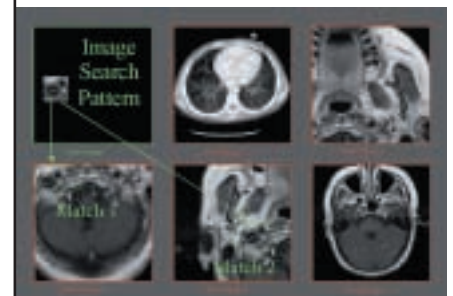
One of LIPS’ most recent tele-health projects, **Ohana Health**, is pioneering revolutionary changes in health information and service delivery over communication networks. Conducted as a Web-based collaboration among research, clinical, and commercial partners, LIPS is providing the technology foundation and system integration for **empowering patient self-care through remote monitoring and screening**. The process involves the patient taking vital measurements with devices at home and transmitting the data regularly via the Internet to a central system, which in turn coordinates multiple data sources for the individual and provides screening analysis for the care-giving team (doctors, nurses, lab technicians, etc.). The system intelligence functions (computer assisted monitoring and screening) deliver analytical reports and response advice to assist both patients and physicians.

Enhanced healthcare effectiveness due to improved patient compliance and physician responsiveness using this system has already been amply demonstrated. With further technological extensions (e.g., using wireless communications and wearable “intelligent” devices), this system can support a **“virtual clinic”** capable of providing patient observation and support anywhere at any time. Although the fictional bionic man/woman may still be far fetched, achieving remote, network-supported health monitoring and care for the active, mobile human is a realistic and achievable goal in the near future.



Courtesy KMC

Kuakini Health System’s new **SONY PetaSite mass Storage Date System** in Honolulu.



Courtesy LIPS/UH

Pioneering research and development at **LIPS** encompasses a broad spectrum of ongoing activities in 3-D image processing and object modeling. Laboratory researchers have developed a **new associative computing model**, based on holographic principles, that is facilitating research into thousands of image databases in logarithmic time. An effort is underway to establish a content-based image retrieval system that would support visuo-logical queries into massive (64K x 32K) image archives based on object similarities using the **IBM Power3 technology** at the **Maui High Performance Computing Center**. The practical implications for medical professionals are manifold - from **rapid location of patient images** among thousands of patient files to **detection and identification of tumors** in radiographic images.

INFORMATION TECHNOLOGY

From High Performance Computing to Interactive Entertainment

Courtesy MHPCC



Ranked as one of the most powerful computational centers in the world, the **Maui High Performance Computing Center (MHPCC)** is managed by the University of New Mexico under a cooperative agreement with the United States Air Force Research Laboratory. MHPCC's **IBM Power3 and Linux Supercluster** system provide general scientific computing resources for the Department of Defense **High Performance Computing Modernization Program** and Hawaii-based military organizations, including the **Maui Space Surveillance Site**. MHPCC offers a **robust parallel processing environment** for advanced image and signal processing, development and testing of high performance computing programming tools and applications software, and **innovative educational and training programs**. In addition to the Department of Defense, MHPCC clients include more than 850 other academic and commercial users from 42 states and the District of Columbia, as well as from 17 foreign countries. MHPCC supports the **Pacific Disaster Center** in Hawaii, providing disaster modeling, warning and response services. MHPCC also supports the **Pacific Missile Range Facility** on Kauai in advanced weather monitoring, advanced radar signal processing, electromagnetic force modeling, and wide-area network communication connections for command and control applications. Other applications include **advanced 3-D image processing techniques** that are particularly relevant to the entertainment, biomedical and architectural communities.

SUPERCOMPUTING CAPABILITIES

- ◆ **Image Processing and Signaling** converts raw data from electro-optical sensors, seismic instruments, radars, and satellites into meaningful information. Advances in collecting, processing, and storing spectral, radar, and seismic data are helping astronomers explore the solar system, military groups observe space objects, petroleum engineers develop new oil fields, and environmentalists track natural disasters.
- ◆ **Modeling and Simulation** uses mathematical emulators and prototypes to facilitate decision-making. MHPCC's computation, storage, and communications capabilities can facilitate high-resolution terrain images for use in combat and for disaster mitigation; digital animations for education, training and entertainment; and 3-D imagery for scientific and medical use.
- ◆ **Scientific Computing and Research** in such fields as computational chemistry, fluid dynamics, and biology is supported by MHPCC's IBM Power3 and Linux Supercluster computing technologies and extensive programming tools, libraries, and application software.
- ◆ **Education and Outreach** is supported by MHPCC to promote the training of tomorrow's leaders in technology. MHPCC works closely with the Hawaii State Department of Education and the Hawaii Association of Independent Schools in supporting such activities as summer intern programs, Project EAST, Women In Technology, Future Scientists & Engineers of America, Internet for Education, Career Days, Hawaii Networked Learning Communications, Tech Ready, MentorNet, and the USS Bowfin Project.

Hawaii is an ideal location for the software development industry, as recognized by a number of firms that have made the state a major base of operations for their company.

Square USA, Inc. is a subsidiary of Tokyo-based Square Co., Ltd., which is the leading third party developer and publisher of interactive entertainment software in Japan. Square Co., Ltd. became famous for its role-playing interactive entertainment software, including its world-renowned *Final Fantasy*™ (which has sold more than 31 million units to date), and now publishes other titles under the SquareSoft brand spanning all genres.

Square USA's Honolulu Studio is breaking new ground with the production of the first computer-generated animated feature film with HyperReal human characters, bringing together the world's top creative talents in the computer graphics and feature film production industries. Produced at the Diamond Head Film Studio and at Square USA's Honolulu Studio at Harbor Court, the motion picture *Final Fantasy: The Spirits Within* is being released in July 2001 and distributed worldwide by Columbia Pictures. "Square selected Honolulu because of its centralized location in the Pacific. This has enabled us to maximize the most creative and experienced talent from all over the world to explore their creativity to new realms," said Jun Aida, President of SquareUSA. "We have been encouraged by the reception we've received here."

The Department of Information and Computer Sciences at the University of Hawaii hosts a **Collaborative Software Development Laboratory (CSDL)**, whose mission is to provide a physical, organizational, technological, and intellectual environment conducive to collaborative development of world-class software engineering skills. Current research projects include the use of an e-commerce simulation environment to support development of entrepreneurial skills; the design, implementation, and evaluation of tools and methods for empirically-based, individualized software developer improvement; the design and use of a hierarchical size counting mechanism for software estimation and planning; and the design and implementation of a client-server-agent system for implementing domain-specific, collaborative, hypertext systems, among other areas.

Additional examples of private sector software developers include:

- ◆ The **Hawaii Multimedia Corporation** – a Microsoft Certified Solution Provider offering services and products supporting website development and hosting, software and applications development, multimedia presentations and software, graphic design, and custom programming and maintenance.
- ◆ **Six D** – an innovative firm creating "next-generation" software products for web development and media design to support corporate presentations, broadcast video, the Internet, interactive CD-ROM & DVD, and kiosk projects for a broad range of businesses.
- ◆ **Computer-Aided Technologies International, Inc. (CATI)** – an Oahu-based company specializing in requirements analysis, CADD systems, integration and disaster planning, graphics, and specialized training in AutoCAD, 3-D Studio MAX, and other high-end multimedia software packages.
- ◆ **WorldPoint Inc.** – a pioneer of Web-based globalization business solutions combining multilingual content management systems, Internet translation solutions, and a network of 10,000 professional language translators to enable users to communicate worldwide in any language.



Courtesy Square USA

SOFTWARE DEVELOPMENT



The State of Hawaii has inaugurated an **Internet Portal** to provide enhanced electronic access to government information and services, eliminating the challenges of “normal business hours” and “standing in line.” With the creation of **eHawaiiGov**, the State is taking an orchestrated, forward-thinking and coordinated approach to maximizing both the capabilities of the Internet and the collective resources of Hawaii.

e-COMMERCE & SYSTEMS NETWORKING

The **Pacific Information Exchange, Inc. (PixiNet)**, known as “Hawaii’s Internet ‘Ohana,” consists of three sites – aloha.com, pixi.com and hula.net. The company is one of Hawaii’s oldest ISPs, providing extensive Internet services for businesses, individuals, seniors, students and the military since August 1994. It was preeminent in facilitating Internet services for the state’s business community, and the first Hawaii-based ISP to provide T-1 bandwidth for access to the Internet. PixiNet was also selected by Honolulu’s **Bishop Museum** and the **Polynesian Voyaging Society** as the Internet Service Provider for satellite Internet communication for a 7-month canoe voyage to and from Rapa Nui. PixiNet joined **NASA, Outrigger Hotels and Resorts**, and **‘Olelo Community Television**, in providing funding, services and technical support for telecommunications with **Hokule‘a** and her escort boat **Kamahele**.

Located in Honolulu, Hawaii, the **Adtech Division of Spirent Communications, Inc.** is a leader both in the global telecommunications industry and Hawaii’s growing high-tech community. Founded in 1967 by three University of Hawaii electrical engineering professors, Adtech designs, manufactures, and markets state-of-the-art telecommunications test systems. The company’s flagship product, the **AX/4000 Broadband Test System**, is a modular, multi-port system that generates broadband test traffic, analyzes full-rate traffic in real time, and simulates network-induced delays and quality of service impairments. Adtech AX/4000 Broadband Test Systems are playing a key role in the development and deployment of the Internet and broadband telecommunications technologies. The Adtech Division also designs and markets network simulation and emulation products, such as the SX Series Data Link Simulators, which create the same delay and error characteristics found in land-based and satellite data links and are used to stress test networks, network equipment, and applications. Adtech is one of Hawaii’s largest and fastest growing high-tech employers, and in 2000 was honored by Governor Ben Cayetano as **Hawaii’s Exporter of the Year**.



Adtech AX/4000 Broadband Test Systems are used by the world’s leading telecommunications companies to test very high speed networking equipment and large scale networks, including the Internet. The award-winning systems feature a modular architecture that supports many different networking technologies and **provides testing at speeds up to 10 billion bits per second**.

Courtesy Spirent Communications, Adtech Division

The **Laboratory of Intelligent and Parallel Systems (LIPS)** at the University of Hawaii provides a broad scope of advanced research and development expertise in the engineering of software, systems and applications using parallel computing and distributed networking. LIPS has developed a powerful technique for planning, scheduling and optimization, known as **Constrained Resource Planning (CRP)**. CRP is both a general methodology for guiding any heuristic problem-solving process and a stand-alone executable engine for resource management under tight constraints, and has been applied to solve more than 40 exponential running time problems with remarkable solution quality and efficiency. Well-known difficult problems successfully solved by CRP include Traveling Salesman, Job-shop Scheduling, 3-D Packing, 3-D Model Recognition, Multiprocessor Scheduling, and Subgraph Isomorphism. These problems illustrate CRP's capacity in handling any of the **six broad application patterns: Production Optimization; Space Utilization; Occupancy Planning; Inventory Distribution; Facility Reservation; and Work-Shift Scheduling**. Recent applications and extensions of the CRP technique has lead to advances in (a) automatic/algorithmic discovery of workflow models from collections of valid execution logs; (b) robotic navigational path planning and obstacle avoidance; (c) static network (re)configuration and dynamic traffic (re)routing; (d) dynamic multi-processor scheduler with simultaneous optimization of processor utilization and job completion time; and (e) 3-D protein structure matching by solving the Maximal Clique, Minimal Coloring and Maximum Common Subgraph problems.

Pioneering research and technology development at LIPS encompass a broad spectrum of ongoing activities in **3-D image processing and object modeling**. The algorithms and software developed at LIPS provide an innovative (patent pending) solution to the surface mesh generation problem that achieves guaranteed quality of fit while increasing computational speed and minimizing storage/transmission requirements. The 3-D triangulation process using LIPS's own constrained resource planning (CRP) technology to obtain a near optimal polygonal surface approximation of 3-D objects in near linear time provides the underlying core technology. Several categories of noteworthy (derived or related) technologies reveal the breadth and vitality of this R&D agenda.

LIPS is equipped with state-of-the-art **3-D graphical visualization and rendering hardware and software**. It supports ongoing research in various **image compression techniques**, and has obtained NASA funding to develop sharable parallel image compression algorithms based on neural networks and adaptive vector quantization. LIPS software system is capable of extracting 3-D information from 2-D images or drawings and rebuild a 3-D object model by **Image Registration**.

LIPS also specializes in **Content-based Image Retrieval** – a new associative computing model, based on optical holographic principles, which enables inherently parallel search into massive image databases in logarithmic time. This capability has expanded the horizon of content-based image search, enabling new possibilities for practical applications of content-based retrieval to target recognition in radar images and tumor detection in medical images, as well as to facilitate collaborative data mining from surveillance images.

PLANNING & SCHEDULING



Courtesy UH Relations

Professor David Y.Y. Yun, Director of the **Laboratory of Intelligent and Parallel Systems (LIPS)**, views a data base for graphic visualization and rendering. The unifying theme of LIPS – that of a distributed but collaborating “**virtual laboratory**” – is emerging in the form of technology integration and delivery of application services based on remote access of mobile/distributed data and computing resources through the Internet (or other high speed networking), with 2-D graphics or 3-D visualization for end users anywhere at any time.

3-D VISUALIZATION & GEOMETRIC MODELING



The **Digital Media Center**, part of the Distance Education and Instructional Technology group within Information Technology Services at the University of Hawaii, was established in October 1996 to provide faculty and staff training and support in the use of various digital/multimedia equipment and software. It assists in areas such as multimedia presentations, interactive CD-ROMs, instructional and departmental web site development, computer-based instruction, video/audio digitizing and editing, and graphics support.

EDUCATION AND TRAINING

Founded by three university professors in 1973, **ORINCON** is a private research and development company focusing on **applied information technology** and dedicated to solving complex, real-world problems through the introduction of advanced technologies such as data fusion, signal processing, image understanding, artificial intelligence, probabilistic reasoning, neural networks, and cognitive theory. With locations in Virginia, California and Hawaii, ORINCON supports a wide range of application domains, including **information security, vehicle/object tracking, antisubmarine warfare, machinery diagnostics and prognostics, planning, health sciences, and transportation**. The business strategy is to develop advanced concepts for research labs and incorporate them into real systems for the Department of Defense, where value added technology can be clearly demonstrated, and to transfer technology to products to be used by other government organizations and commercial customers.

Solipsys Corporation – a small, high technology business specializing in products for defense application – has created products that reflect a unique combination of the best commercial practices and an in-depth understanding of the challenges facing the military services. Its primary corporate focus is the development of products designed to address the multifaceted problem of Joint and Coalition Forces information networking. Solipsys' expertise lies in **sensor automation, information synthesis, networking and communications, and visualization**. Many of the company's information synthesis and visualization products are being used to meet the demands of test range operations. With an office at the **West Kauai Technology & Visitor Center**, Solipsys services the **Pacific Missile Range Facility**, which employs Solipsys products to automate planning and execution of range test events.

Another company servicing PMRF out of the West Kauai Technology Center is **Digital System Resources** – a recognized leader in the development and production of defense systems involving **passive and active sonar, electronic warfare, combat control, and computer based training and simulation** for these systems. In the commercial sector, the company's **e-Commerce System Group** is focusing on the Internet-based business to business (B2B) sector. The company's goal is to apply its proven technical expertise in developing high quality complex systems to the fast paced and rapidly changing world of eCommerce. Services include a comprehensive range of Internet, Extranet, and Web site solutions.

Honolulu Community College (HCC) has partnered with **Cisco Systems, Inc.**, the worldwide leader in networking for the Internet, to serve as a Cisco Academy Training Center, providing Cisco-approved instruction leading to both the Cisco Certified Network Associate (CCNA) and Cisco Certified Network Professional (CCNP) designations. Courses include the basic theoretical foundation in "internetworking" required to implement networking solutions in the real-world. However, a majority of the time in class is spent participating in labs designed to help students learn how to use the networking equipment and tools. These courses tend to be quite popular because of this "hands-on" emphasis.

The **Computing, Electronics and Networking Technology (CENT)** at **HCC** is a two-year program of study that prepares students for employment in the electronics and computing industries. Through a choice of electives in the third and fourth semester of study, students can choose to concentrate on a particular area of interest. Such areas could include telecommunications, product servicing, computers and networking, and biomedical applications. Where possible, students are encouraged to participate in an internship cooperative education experience in the fourth semester of study.

A high-tech economy demands a **highly skilled workforce**. Businesses must be able to hire and keep skilled and knowledgeable workers and utilize advanced technologies to better serve their customers. Local governments must keep and attract new businesses to grow economically. To meet this workforce need, a **consortium of the University of Hawaii Community Colleges** has taken the lead to increase access to training by developing the **Pacific Center for Advanced Technology Training (PCATT)**. Though headquartered at Honolulu Community College, PCATT is composed of all the University of Hawaii Community Colleges and offers services and training statewide.

More than a collection of physical facilities, PCATT is a commitment of the University of Hawaii Community Colleges to reach, enhance, and add value to businesses through the development of a skilled and knowledgeable workforce in Hawaii. Its **mission** is to **develop and provide training in advanced technology applications that enhance economic and workforce development programs and initiatives in the State of Hawaii and the Pacific Rim**. It builds upon training programs already in place at campuses throughout the system to offer a coordinated, one-stop approach to the design and delivery of customized training in advanced technologies.

In addition to regularly scheduled courses at community colleges, PCATT offers **customized training packages** to meet specific training requirements of business and industry. These packages can be tailored with regard to content and schedule and in many instances can be offered on-site, depending on equipment requirements. Current Technology Training include Computer Aided Design, Computerized Apparel Applications, Database Management, E-Business, Electrical Control, Graphics and Digital Media, Networking (including MCSE and Cisco), Programming, Solaris System Administration, Telecommunications, and Web and Internet modules.

Distance learning provides students with access to education through a network of UH education centers and various technologies. In addition to the seven Community Colleges and the Employment Training Center, there are distance learning education centers located on Molokai; Lanai; Hana, Maui; Waianae, Oahu; and in West Hawaii. Courses are also offered on select military bases and in correctional facilities.

The **University of Hawaii** has achieved a breakthrough in its **distance learning curriculum** by establishing an MBA program where students in remote classrooms on each of the Neighbor Islands can work toward graduate degrees without having to travel to the main campus on Oahu. Two-way television systems are set up where instructors and students can interact in a classroom-like atmosphere. The established facilities include a web site with chat rooms and allows for communication with lecturers via e-mail. Instruction is provided by the College of Business Administration, one of the nation's top internationally oriented business schools. Potential exists for distance instruction in areas of entrepreneurship, management, and e-commerce, with particular reference to Asia-Pacific nations which have indicated preference for such remote learning programs.



Distance Learning at the **University of Hawaii** provides opportunities for quality higher education to students anywhere in the state who are unable to attend the UH campus offering their program of choice. Distance learning includes telecommunications-assisted learning and off-site learning, and may take place in-state or out-of-state.

DISTANCE LEARNING

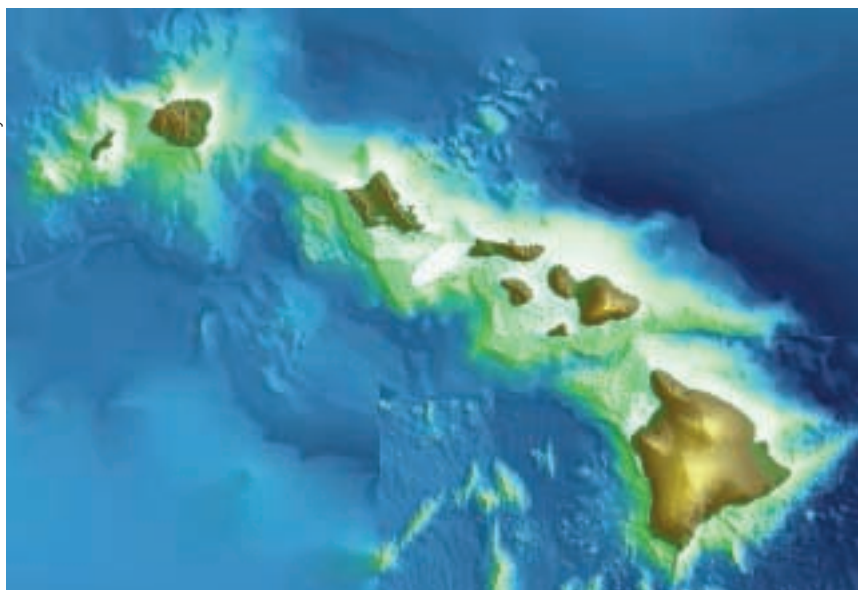
An assortment of **distance learning resources and technologies** are provided for students who are committed to higher education but are unable to attend a UH campus offering their program of choice. Courses are delivered in a variety of ways, including:

- ◆ **Cable Access Television** provides UH a tool to distribute pre-produced or live cable programming directly to homes, and on Oahu is facilitated by 'Olelo – the island's community access provider.
- ◆ The **Hawaii Interactive Television System (HITS)** is an interactive inter-island closed-circuit television network providing full-motion (not compressed) analog video services, with 4 outgoing channels from UH Manoa to all sites.
- ◆ The **Oceanic Cable Digital Video Institutional Network (I-NET)** is a 16-channel high-speed digitized video and audio transport between UH campuses on the island of Oahu for instructional use.
- ◆ The advent of the **World Wide Web** and the development of course management tools have made the Internet a viable distance learning tool.
- ◆ **IP-Based Video** (H.323 standard) provides 2-way videoconferencing capabilities over IP data networks for guest lectures and periodic connections with classes throughout the world for student collaborations.
- ◆ Compressed digital video over **ISDN (Integrated Services Digital Network)** phone lines provides two-way dial-up video conferencing.
- ◆ UH can receive **satellite programs** via downlink facilities of the **UH Manoa Language Telecommunications Resource and Learning Center (LTRLC)** or at **Hawaii Public Television**. The LTRLC also operates a **satellite uplink** facility which can be used to broadcast live video programs from Hawaii to the Mainland and Asia/Pacific regions.
- ◆ **SkyBridge** is Maui Community College's microwave system which serves the three islands of Maui county, providing one channel of 2-way video among Maui CC and its education centers on Molokai, Lanai and in Hana, Maui.

OCEAN SCIENCE & TECHNOLOGY

From Deep Water Marine Research to Coastal Resources Management

Courtesy SOEST/UH



This image illustrates the **land topography and seafloor bathymetry** compiled on a 9-second resolution grid, using **Wessel and Smith's GMT-System** at the **School of Ocean and Earth Science & Technology (SOEST)**, University of Hawaii.

UNIVERSITY-BASED R & D

Courtesy SOEST/UH



The submersible **Pisces V** being recovered by the **R/V Ka'imikai-o-Kanaloa**.

Hawaii's strategic mid-Pacific location, diverse geologic and marine resources, state-of-the-art technology infrastructure, and professional expertise in marine science and technology make the islands an unparalleled natural laboratory for ocean research and development.

- ◆ The islands' volcanic origin and lack of continental shelf facilitate ready access to **pathogen-free, nutrient-rich deep water** and an impressive variety of **coral reefs, estuaries, ancient seamounts, manganese crust deposits, and a tectonically active submarine ridge**.
- ◆ Nearly 30 commercial and small boat harbors, including the University of Hawaii's Marine Center at Snug Harbor, form an intricate network for surface support of sea-going operations in and around the islands.
- ◆ Lying within the second-largest U.S. Exclusive Economic Zone, Hawaii affords clear legal access to **vast living and mineral resources**, as well as a time zone that enables **communications with both eastern and western hemispheres within the same business day**.

Ocean science and technology centers statewide have a strong university presence at their foundation. The University of Hawaii at Manoa's **School of Ocean and Earth Science and Technology (SOEST)** and its affiliated research institutes support a broad range of marine and ocean-related R&D programs, federal funding for which contributes millions of dollars to Hawaii's economy annually. From studies of small-scale waves to ocean circulation models to primary productivity and mineralization processes, **SOEST programs and projects consistently rank among the top five in the nation for National Science Foundation peer-reviewed funding**. SOEST also excels nationally in research related to **coral reef ecology, tropical aquaculture, and renewable energy**. In January 2002, the University of Hawaii will add a new **\$45 million SWATH research vessel** to the University's research fleet (see also *Defense & Dual Use Technology*). These stellar achievements have attracted some of the nation's best and brightest scientists and students to study and live in Hawaii.

Examples of SOEST institutes and programs include:

- ◆ The **Hawaii Undersea Research Laboratory (HURL)** at the University of Hawaii makes state-of-the-art deep water marine research facilities available to academic and research institutions through an annual request for proposals. Research facilities include the **Pisces IV and V submersibles**, with a depth capability of 2,000 meters; the **RCV-150** remotely operated vehicle; and the research vessel (R/V) **Ka'imikai-o-Kanaloa** mother-ship with its **Sea-Beam 210 bathymetric mapping system**. These assets provide scientists with a full complement of the latest marine research technologies and allow them to range throughout the South Pacific.

- ◆ The **Hawaii Institute of Marine Biology (HIMB)**, located on a coral reef preserve in Kaneohe Bay, supports research in coral physiology and reef ecology, the behavior and population dynamics of fish, marine endocrinology, aquaculture, and marine mammals.

- ◆ The **Sea Grant College Program** supports research, education, and extension services for improved understanding, management, and use of coastal and marine resources.

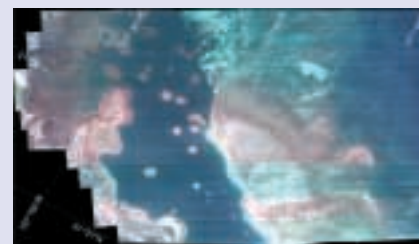
- ◆ The **Hawaii Mapping Research Group (HMRG)**, an organization of scientists and engineers, builds and operate 5 seafloor mapping systems. HMRG's MR1 side-scan sonar helped locate the USS Yorktown.



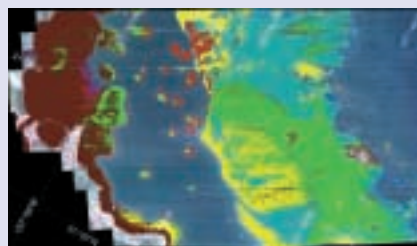
Courtesy HIMB/UH

The Hawaii Institute of Marine Biology

The images to the right illustrate an example of pioneering research being done in Hawaii to help understand and protect marine ecosystems. HIMB's **Coral Reef Color Laboratory (CRCL)** is developing the use of airborne and satellite-based digital remote sensing to study coral reef environments. Algorithms are being developed for image calibration, geomorphology mapping and biological mapping, with the goal of developing a system for analysis of benthic pigment composition and concentration using remote sensing imagery. Dr. Eric Hochberg, CRCL scientist, is supporting this effort by developing algorithms for **correcting remote sensing imagery for water column radiative transfer effects** and for **classifying images into ecological groups**. This mosaic was constructed for the State of Hawaii's Department of Business, Economic Development & Tourism. The top image shows central Kaneohe Bay in RGB (600, 539, 478 nm). The bottom image shows the RGB superposed by a classified image. Colors in the image represent coral (red), coralline algae (pink), macroalgae (green), terrigenous mud (brown), sand and rubble (yellow), and turf algae (dull blue-green).



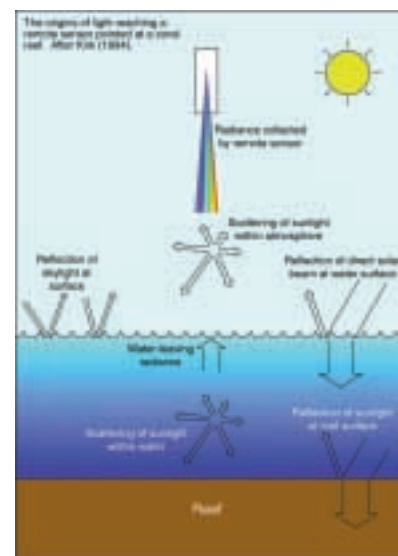
Courtesy HIMB/UH



The **International Pacific Research Center (IPRC)** was established under SOEST in October, 1997, under the "U.S.-Japan Common Agenda for Cooperation in Global Perspective" as a collaborative global-change research effort between Japan and the United States. Its purpose is to provide an international research environment dedicated to improving understanding of the nature and predictability of climate variability in the Asia-Pacific sector, including the influences of global environmental change within the Asia-Pacific region. Its goals are to:

- ◆ **understand climate variations** in the Pacific and Indian Oceans on interannual-to-interdecadal time scales;
- ◆ **determine the influences on Asia-Pacific climate** of western-boundary currents, the Kuroshio/Oyashio Extension system, marginal seas, and the Indonesian Throughflow;
- ◆ **understand the processes responsible for climatic variability** and predictability of the Asia-Australian Monsoon System and its hydrological cycle at intraseasonal through interdecadal time scales; and
- ◆ **identify the relationship between global environmental change and Asia-Pacific climate.**

IPRC's overall research strategy emphasizes **diagnostic studies, modeling, and data assimilation**. Collectively, the above goals will contribute to international efforts under the World Climate Research Programme and the International Geosphere-Biosphere Programme.

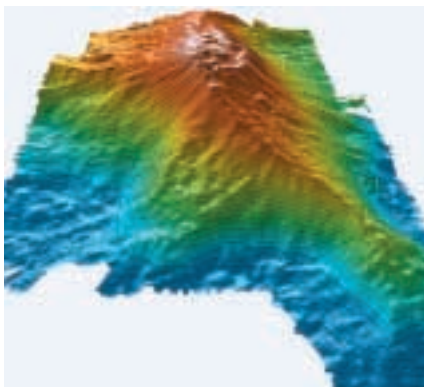


Courtesy HIMB/UH

Radiative Transfer Modeling - This diagram illustrates the five origins for light that reaches a remote sensor pointed at a coral reef.

OCEAN INDUSTRIES

Courtesy HURL/SOEST-UH



Loihi is an active submarine volcano that may become the next Hawaiian Island. The most hydrothermally active area of the volcano is presently located along the southern rim and rift. Dives on the hydrothermally less active northern rim showed relatively stable terrain as compared to that observed earlier, and high lava columns were still standing upright. A new **SeaBeam bathymetric map** of Loihi (above) was generated aboard **Ka'imikai-o-Kanaloa** and verified during **Pisces V** dives (see previous pages), precisely documenting the morphological changes at the summit.

The **National Defense Center of Excellence for Research in Ocean Sciences (CEROS)**, located at the **Natural Energy Laboratory of Hawaii (NELH)** at Keahole Point on the island of Hawaii, is a federally funded program that seeks to advance innovative concepts and new approaches to technology while fully leveraging existing facilities and infrastructure in Hawaii and demonstrating beneficial commercial utility for the Department of Defense. Since 1993, the CEROS Research Programs have funded a total of 116 projects at a value of over \$46.12 million (see also *Renewable Energy*). The **Ocean Resources Program** of the **Hawaii Natural Energy Institute**, also located at NELH, operates a **Center for Ocean Resources Technology** to conduct interdisciplinary research on open-ocean mariculture, as well as a **Marine Mineral Technology Center** to meet ocean mineral and mining research needs.

The **Natural Energy Laboratory of Hawaii Authority (NELHA)**, which manages NELH, is currently partnering with the National Defense Center of Excellence for Research in Ocean Sciences (CEROS), University of Hawaii (Manoa and Hilo), Hawaii Natural Energy Institute, Marine Bioproducts Engineering Center (MarBEC), Kohala Research Center, University of California - Santa Barbara, and New Mexico Tech to establish the **NELHA Gateway** – a world-class research, education, and outreach center to be located at the entrance to NELH. Gateway research will focus on **emerging technologies in energy, climate, and defense related challenges and innovations**. In particular, this facility will become the **premier focal point for distributed generation technology, fuel cells, and hydrogen in the United States**, giving industry not only access to world class researchers, but also to facilities where testing and deployment in real world conditions can occur. The center will **integrate efforts to deploy distributed generation and clean energy technologies** for several federal agencies, DOE laboratories, universities, and the private sector. In addition, Gateway will showcase the natural environment and unique resources available at Keahole Point to the public through **educational programs and exhibits**.

Over the past two decades, **Hawaii's ocean science and technology industry has grown from \$20 million in annual revenues to \$100 million**. Commercialization of Hawaii's ocean-oriented research and development programs has been a major milestone in this growth. Local companies are making scientific instruments and software packages for global markets. Such products and services include **high-resolution ocean floor maps, hyperspectral imaging services for coral reef mapping, software for modeling tensions on undersea cables, instruments to perform sub-bottom mapping, ocean rescue devices, and fish poison test kits**. Some examples of companies offering these products and services include:

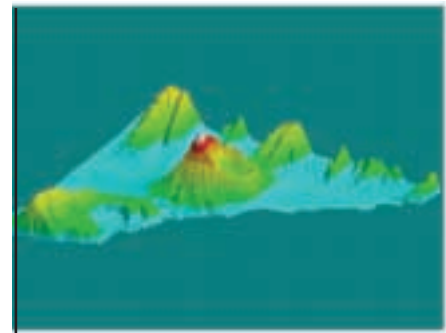
- ◆ **Oceanit**, a Hawaii-based engineering and research company focusing on biotechnology, information technology, environmental and industrial technology, has developed the innovative Flexible Pipe Diffuser that conducts sediments contained in dewatering effluent from harbor construction to the harbor bottom, thereby minimizing plumes in coastal waters.
- ◆ **Structural Solutions** has developed CableCAD, a comprehensive cable design tool for laying out cable geometry and a powerful analysis program which reduced design time and lowers design costs.
- ◆ **Science & Technology International (STI)** acquires and processes spectral information about objects to facilitate underwater coral discrimination to assess reef health, as well as to monitor pollution caused by oil slicks and ground runoff.
- ◆ **Makai Ocean Engineering, Inc.** provides ocean engineering services world wide and supplies submarine cable installation and planning software, designs and places deep water pipelines, and provides research and design services for a wide array of ocean and coastal applications.

- ◆ **Sea Engineering, Inc.** and **Precision Signal** of Boca Raton, Florida are developing a forward/aft - port/starboard sweeping, high resolution buried object imaging sonar for locating and imaging small objects buried beneath the seafloor.
- ◆ **Oceanic Imaging Consultants, Inc.** has produced the OICToolkit – a powerful and comprehensive UNIX-based package for processing sidescan and bathymetry data, which can import data from all major sonar systems, process navigation and attitude, correct beam patterns, enhance imagery, mosaic the data, and export final images to other GIS and mapping packages.
- ◆ **ORINCON Hawaii, Inc.** provides signal and information processing to support algorithms for application to shallow and deep water, passive and active sonar and mine countermeasure systems.
- ◆ **TerraSystems, Inc.** specializes in airborne and satellite spectral imagery which offers the ability to identify and discriminate among many types of materials including various types of vegetation, coral, sand and algae; and submarine sand deposits.
- ◆ **SEE/RESCUE Corporation** has created the patented and military-approved SEE/RESCUE streamer technology for locating persons lost at sea or on land. It is the only “passive” and “continuous” distress signaling device.

Coastal Resources Management is a growing segment of Hawaii’s Ocean Science and Technology Industry. Presently the smallest component of the industry, this area focuses on the huge worldwide market for providing consulting, planning, engineering, architectural, legal, and policy expertise and services for coastal cleanups and resort, harbor and infrastructure development. Multilateral organizations such as the US Agency for International Development (USAID), the World Bank, and the Asian Development Bank are funding numerous projects in Asia, which is a logical market for a host of Hawaii-based service providers.

Hawaii is also home to a **prestigious assembly of ocean- and marine-related associations and organizations** that sponsor diverse seminars, workshops, conferences, and outreach programs addressing the needs of nations throughout the Asia-Pacific region. The **Pacific Science Association** and **PACON International**, which organizes the biennial **Pacific Congress on Marine Science and Technology**, have their headquarters in Honolulu. Non-profit organizations such as the **Oceanic Institute**, renowned for its pioneering work in aquaculture and oceanography, and the **Pacific International Center for High Technology Research (PICHTR)**, provide expertise supporting ocean R&D projects worldwide.

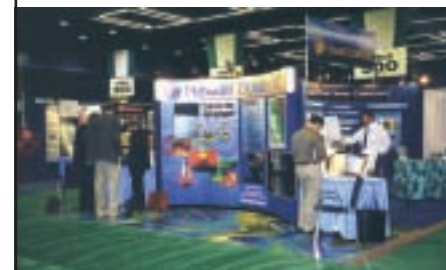
The future for Hawaii’s ocean industries looks bright. **Hawaii ranks high nationally in the receipt of federal ocean R&D dollars.** The state’s ocean science and technology strengths are also attracting **increasing investments from both private and government sectors** in such diverse areas as Japan, Korea, Singapore, Venezuela, American Samoa, Australia, Canada, England, and Taiwan. Hawaii’s economy currently gets an average of \$2 to \$3 million annually from Chinese, Japanese, and Korean groups prospecting for marine minerals on the sea bottom south and east of Hawaii. The need for coastal states to **explore the resources within their 200-mile Exclusive Economic Zones** will also provide Hawaii’s ocean science and technology industries with new markets for their products and services. In March 2001, Hawaii granted its first **open ocean commercial lease for large-scale cage culture** – a commercial venture that arose from a cooperative pilot program carried out by the private sector, University of Hawaii and state government. Finally, **remote sensing and sophisticated ocean mapping technologies** will play a large part in determining the direction of Hawaii’s ocean science and technology future by making it possible to assess resources and environmental impacts over large areas in a reasonable time frame and at affordable cost.



Courtesy PMP

This image of the area around **Hanauma Bay** on the island of Oahu was developed at the **Pacific Mapping Program (PMP)**, located within SOEST. PMP was established to **facilitate the exploration and development of the Pacific Islands Exclusive Economic Zone (EEZ)**. This unique program **conducts research, performs services, and offers graduate education in ocean mapping.** Research highlights include integration of various types of available mapping data in the EEZ of the Pacific Islands Region (Hawaii, Guam, American Samoa, and Northern Marianas), and the investigation of new data integration methods and data analysis techniques. PMP is also developing a Marine Geographic Information System, a correlation study between free-air gravity anomaly and bathymetry, and research into navigational problems using GPS.

PROFESSIONAL ORGANIZATIONS



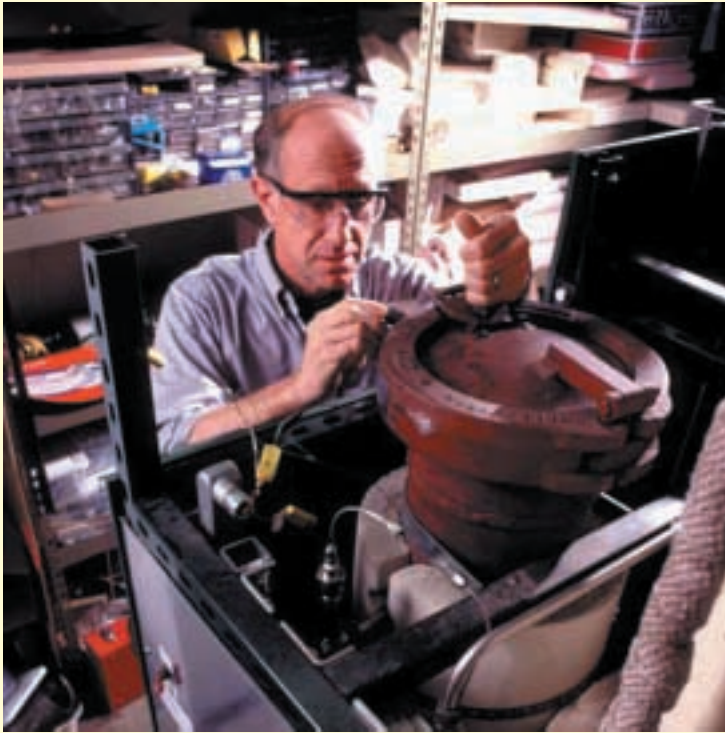
Courtesy ERTD/DBEDT

Hawaii is hosting an increasing number of **conferences and exhibitions related to ocean science and technology.** For example, in just a two-week period in 2001, Hawaii was selected as the site for the annual conference and exhibition of the Marine Technology Society and the Oceanic Engineering Society/IEEE, the Underwater Defense Technology-Hawaii Conference; and the annual meetings of the U.S.-Japan Natural Resources Marine Facilities Panel and the Underwater Mining Institute.

RENEWABLE ENERGY

Harvesting Resources from Sun, Wind, Earth & Ocean

Courtesy HNEI/UH



Some of Hawaii's most creative and novel developments in the field of biomass energy technologies have come from the **Renewable Resources Research Laboratory** of HNEI at the University of Hawaii. The lab has been particularly adept at developing sustainable technologies that are suitable for commercialization. Innovative processes currently in use or under development include fractionating biomass using hot, compressed water, and gasification of high-moisture-content biomass.

ALTERNATIVE ENERGY SOURCES

A geologically young and isolated island chain, Hawaii has emerged as a world leader in the demonstration and use of renewable energy as an alternative to imported oil. Export potential is being developed in wind and solar technologies (both thermal and photovoltaic) and hybrid systems for island applications. Additional prospects reside in the development of biomass gasification and direct combustion, geothermal energy, alternative transportation fuels, wave energy systems, and ocean thermal energy conversion (OTEC) technologies.

State-Supported R&D

The **Hawaii Natural Energy Institute (HNEI)** was established by the Hawaii State Legislature in 1974, in the aftermath of the world's first oil crisis. Recognizing the promise of indigenous resources, the Legislature established HNEI as a research unit of the University of Hawaii with a mandate to **undertake and coordinate research and development of the Hawaiian Islands' renewable energy resources that would reduce the state's dependence on fossil fuels.** In its early years, HNEI served as a catalyst for interdisciplinary cooperation among faculty from the University of Hawaii; federal, state, and local governments; private industry; public utilities; foreign governments; community groups; and other research units throughout the world. In doing so, HNEI has become an acknowledged international leader in the energy field. In 1988, HNEI

moved into the University of Hawaii's School of Ocean and Earth Science and Technology (SOEST) and has broadened its expertise to encompass a variety of ocean- and energy-related technologies.

Today, the Institute's responsibilities include conducting and supporting basic research, managing research facilities and laboratories, demonstrating the applications of its work, and investigating the social, environmental, and financial impact of energy- and marine-related activities. HNEI's current programs embrace research and development projects related to **biomass-derived products and fuels, renewable hydrogen production, transportation, electrochemical power sources (e.g. batteries and fuel cells) and ocean resources for energy, food, and minerals.** Each of these research areas/programs is supported by state-of-the-art laboratories and highly experienced faculty.

HNEI's **Biomass Program** has been far-ranging, from early work on sugar cane as an energy crop, to energy tree farming, to development of advanced gasification technology for conversion of biomass to gaseous fuel. Some of Hawaii's most innovative and novel development in the field of biomass conversion have come from HNEI's **Renewable Resources Research Laboratory (RRRL).** RRRL researchers have developed a new catalytic process, which

causes biomass to react with water at high temperatures and pressures (supercritical conditions) to produce a hydrogen-rich gas stream. This unique process allows wet biomass to be utilized and produces no tars or char. A patented process for charcoal production awaits commercialization.

HNEI's highly successful **Hydrogen Program**, resulting in HNEI being named a **US Department of Energy University Center of Excellence for Hydrogen Research and Education**, has explored novel approaches for high efficiency, safe hydrogen storage; direct solar hydrogen using photoelectrochemical and photobiological techniques; and various processes for the gasification of biomass. The **Thin Films Laboratory**, used to develop thin-film photovoltaic-like devices for hydrogen production, is also actively involved in development of novel sensors and semiconductor films for optical imaging applications.

During the coming year, and in collaboration with the Naval Research Laboratory, HNEI is expecting to initiate a significant program to **advance fuel cell technology with a supporting effort to characterize and develop marine-based methane hydrates (ice-encrusted concentrations of methane found on the deep ocean floor) as a future fuel source**. Central to this effort, the **Hawaii Energy and Environmental Technology Initiative** will develop a state-of-the-art test center for the characterization of fuel cells and fuel processing technologies.

Biodiesel

Pacific Biodiesel, a Maui-based company, makes an additive for diesel fuel which reduces particulate and smoke emissions from diesel engines. The fuel, called "biodiesel," can be blended with regular diesel in any proportion (or used by itself) to power bus, truck, engine-generator, and marine diesel engines to improve emissions, cetane ratings, and fuel lubricity. The vehicle exhaust from biodiesel-fueled engines is cleaner, safer, and smells better. Even more environmentally impressive is the fact that this biodiesel fuel is made from used vegetable oil, such as that recovered from frying operations in restaurants. The company has built a similar facility in Nagano, Japan. Pacific Biodiesel has partnered with **Honolulu Disposal** to construct new **a biofuel plant in Honolulu**. A large-scale biodiesel plant is also planned for the future.



Richard E. Rocheleau, Director of HNEI, examines equipment in the Institute's "**Thin-Films Laboratory**" – a unique facility boasting sophisticated state-of-the-art equipment for fabrication and testing of thin-film materials (<math><1\mu\text{m}</math> thick) and devices. The lab has developed novel semiconductor, dielectric and catalyst films for a diverse range of applications, including photovoltaics, solar hydrogen-production, and optical sensors.

Courtesy HNEI/UH

Biodiesel-fueled vehicles are used by organizations such as the **Pacific Whale Foundation (PWF)** for sea-based operations. Based in Hawaii, the Foundation is recognized worldwide for **long-term marine research and conservation studies conducted throughout the Pacific**, which collectively help monitor changes in the global status of threatened or endangered species.



The Foundation's award-winning marine education programs have enabled more than 700,000 people to learn about the ocean and the need to protect our planet's seas. Its research findings also help to educate policy makers worldwide on an international, national, state and local level, in favor of laws and policies that protect the marine environment. Pictured above is one of the Foundation's biodiesel-fueled research and education vessels - the Ocean Spirit.

Courtesy PWF



H-POWER (Honolulu Program of Waste Energy Recovery) - H-POWER began operation in 1990 and today converts more than 2,000 tons of waste per day into electricity to power more than 60,000 homes. H-POWER is the cornerstone of Honolulu's integrated waste management system. H-POWER produces 7% of Oahu's electricity and reduces the volume of refuse going to landfill by 90%. On Oahu, waste-to-energy works in partnership with recycling efforts to significantly reduce the amount of waste going to landfills. In addition to reducing the volume of waste entering the plant by 90% through incineration, H-POWER is actively engaged in recycling. Virtually 100% of the ferrous and nonferrous metal is recovered for recycling, and a program for recycling the ash is currently being finalized. The facility's pre-processing system uses magnets to pull metals from the waste stream and eddy current separators extract non-ferrous metals from the ash, diverting approximately 18,000 tons of ferrous metals (tin cans) and 2,500 tons of non-ferrous metals (aluminum cans) to recycling annually. Moreover, H-POWER reduces Hawaii's dependence on imported oil. One ton of trash produces saleable energy equivalent to 60 gallons of oil.

Biogasification

Biomass research conducted by federal, state and private industry scientists has demonstrated the technical feasibility of producing a fuel gas, biogas, from sugar cane bagasse for both power generation and, with further conversion, for transportation fuel in the islands. This research has shown that biogas can fuel an advanced turbine system to produce electricity with a possible 50 percent increase in efficiency. In addition, the technologies developed can enable the widespread use of a cleaner, self-sustaining energy resource designed to demonstrate biomass gasification power generation. Hawaii's assets, such as a highly developed bio-energy infrastructure, resident technical capability in research and engineering, and a benign, year-round growing season, offer unique advantages for developing these state-of-the-art systems.

Biomass Power

Of all forms of renewable energy, biomass offers the best near-term opportunity for supplying a significant portion of the energy needs of developing countries. The use of biomass as a fuel source can reduce dependence on fossil fuels and thereby improve the balance-of-payments for countries that import energy. Biomass production and conversion activities stimulate local economies by providing new employment opportunities for the work force, as well as product and market opportunities for agribusiness. Biomass is also relatively low in sulfur content, carbon dioxide neutral over its production and utilization cycle, and offers environmental advantages over many fossil fuels. Its use eliminates certain potentially detrimental practices such as uncontrolled field-burning or land-filling crop residues.

tially detrimental practices such as uncontrolled field-burning or land-filling crop residues.

Local entrepreneurs have used food waste to generate energy employ anaerobic digestion systems to process organic waste that is unsuitable for burning and not allowed in landfills and wastewater treatment facilities. By-products include organic fertilizer as a replacement for its chemical equivalent, and biogas (methane), employed to both generate electricity and to process heat to run the system.

The "garbage-to-energy" plant on Oahu burns refuse-derived fuel to provide electricity for Oahu's power utility. Materials which do not burn, such as steel and aluminum, are removed for recycling. The plant produces approximately 7% of Oahu's total electricity requirements.

Ethanol

An ethanol investment tax credit, enacted in Hawaii in 2000, seeks to encourage investment in ethanol production facilities. As described above, Hawaii has abundant biomass resources and potential. Several companies in the state are exploring a variety of ethanol production techniques, from traditional fermentation to state-of-the-art lignocellulosic conversion technologies.

Hydrogen Power

Hydrogen has been called **the fuel of the future**. It may be the ultimate environmentally-benign energy carrier – **a versatile, transportable fuel that can be converted easily and efficiently to other forms of energy without producing harmful emissions**. Hydrogen can be used as a fuel for transportation, electricity generation, cooking, and heating. It can be produced from renewable resources, such as electrolysis of water into hydrogen and oxygen using solar or wind energy, or through direct conversion of biomass into hydrogen and other gases. In the past, the cost of production, difficulties in storage, and lack of infrastructure have been obstacles to everyday use of hydrogen. Work is underway in the area of photo-electrochemistry, biomass gasification of hydrogen, and hydrogen storage technologies at the Hawaii Natural Energy Institute (HNEI) to address these issues.

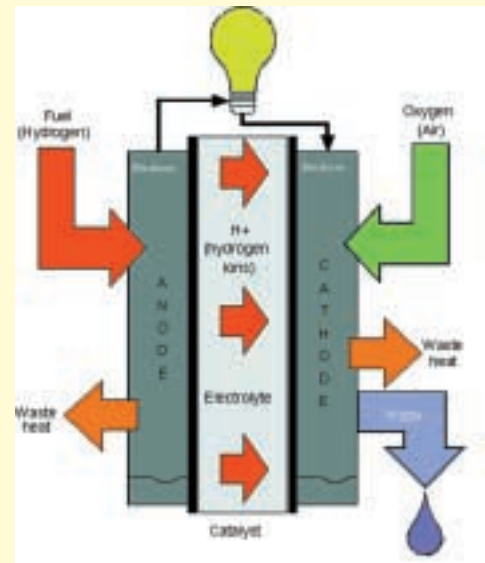
Hydrogen storage has long been a problem. Hydrogen is normally stored as a gas in high-pressure tanks, or as a liquid at cryogenic temperatures. Hydrogen can also be stored as a solid by reacting it with a variety of metals. These materials, known as metal hydrides, provide safe, low-pressure storage; however, historically the amounts of hydrogen have been too small to be practical, or the hydrogen has formed too strong a bond with the metal hydride, requiring large energy inputs for its release. Over the last ten years, HNEI's research has focused on developing "non-classical" polyhydrides – transition metal complexes – as storage media. Experiments showed that this new class of material could store and discharge hydrogen with lower energy inputs than conventional hydrides, thereby hastening the day when hydrogen can become more cost effective in daily use.

Ocean Energy Systems

Ocean thermal energy conversion, or OTEC, uses the difference in temperature between the ocean's warm surface water and cold water in depths below 2,000 feet to generate electricity. With a sufficient temperature difference (about 40 degrees Fahrenheit) between the warmer upper layers of water and colder deep water, power can be generated.

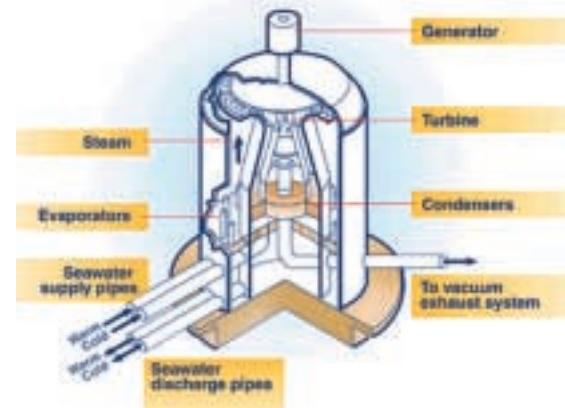
The **Natural Energy Laboratory of Hawaii (NELH)** at Keahole Point on the island of Hawaii is recognized as the world's foremost laboratory and test facility for OTEC and OTEC-related research. The facility has been funded by the State of Hawaii with significant U.S. Department of Energy participation. The prospect of major reductions in the cost of closed-cycle OTEC plants through the application of evaporators and condensers is being investigated at NELH. ALCAN Aluminum of Canada and the Marconi Division of the General Electric Company of Great Britain have also supported this research.

Wave energy systems are also under study at NELH. Such systems must be able to withstand a variety of environmental conditions, including storms, corrosion, and biofouling. They also have to be developed and deployed in an aesthetically pleasing and environmentally sensitive manner. Hawaii's skills and strengths in these areas are important components facilitating this research.



Pictured above is a **fuel cell**, which produces electricity through the combination of hydrogen and oxygen (the only emission is water vapor). Hydrogen, the "energy carrier" that powers the fuel cell, may be produced from water by using electricity from renewable (e.g., solar, wind, hydropower, geothermal) or non-renewable (coal, oil) energy sources. Hydrogen may also be obtained from liquid or gaseous fuels (natural gas, ethanol, methanol, propane, gasoline, etc.) via a device called a "reformer."

Courtesy International Fuel Cells, Inc.



In May 1993, an **open-cycle OTEC plant** at Keahole Point, Hawaii, produced 50,000 watts of electricity during a net power-producing experiment. This broke the record of 40,000 watts set by a Japanese system in 1982. Today, scientists are developing new, cost-effective, state-of-the-art turbines for open-cycle OTEC systems.

Courtesy NREL

Solar and Wind Energy

Hawaii has harnessed other natural energy sources for technological innovation. Hawaii has the **highest per capita use of solar water heating in the United States**. Hawaii is also a **leader in the development of applications of photovoltaics and wind energy**, as well as in sophisticated computer modeling of its statewide energy system. Several solar engineering firms in the state are active in both solar thermal heating and photovoltaic equipment applications servicing clients in the Pacific Islands, South America and the Mainland U.S. Other firms are marketing hybrid solar products, including a patented solar pasteurization process for water purification.

Parker Ranch, located on the island of Hawaii, is one of the largest and oldest cattle ranches in the country. It is also **the home of the world's largest hybrid PV-wind project**: 175 kW of photovoltaics and 50 kW of wind power supply over 90% of the daytime electrical power needed to provide drinking water for Ranch livestock in one of the grazing areas.

During any given day, the combination of sun and wind provide enough energy to run all the booster pumps in the water system that runs 7,000 feet up the side of Mauna Kea. Money saved from reduced utility bills more than covers the amortized cost of the system.

The **Hawaii Islands Humpback Whale National Marine Sanctuary** building on Maui has solar water heaters, a 2.8 kW photovoltaic system, and solar light fixtures. Any surplus solar power (such as is generated on weekends) is sold to **Maui Electric Company**. "Using renewable energy helps reduce the risk of oil spills,

and thereby helps to protect the marine environment – one of our objectives," said Claire Cappelle, Maui County Liaison for the Sanctuary.

Other utility-connected photovoltaic installations include systems at hotels, a car dealership, and schools. The **Mauna Lani Resort** pioneered hotel use of photovoltaics with the installation of two systems that serve both the main hotel (100 kW) and its golf cart charging operation (110 kW). The **Hapuna Prince Beach Hotel** has a 20 kW PowerGuard photovoltaic system and will soon receive 90 new



Frank Hess, Service Operations Manager, **Parker Ranch** (on the left) and John Crouch, Director, **PowerLight Corporation**, shown next to the control building, with three of the five 10 kW wind turbines in the background. The Supervisory Control and Data Acquisition (SCADA) system maximizes the efficiency of the hybrid system by matching electrical load to available solar energy.

Courtesy Parker Ranch



The **225 kW PowerTracker/Wind Hybrid System**, designed and built by **PowerLight Corporation** for Parker Ranch.

Courtesy PowerLight Corporation

solar-powered “SunCaddy” golf carts for their Club Car fleet. A Chevrolet dealership near downtown Honolulu has 50 kW of photovoltaics on its building. Fifteen public schools also have photovoltaic systems installed under a “Sun Power for Schools” program sponsored by the **Hawaiian Electric Company** and its subsidiaries.

In addition, many off-grid (remote) homes have photovoltaic systems with battery and generator backup. Several companies, such as **Inter-Island Solar Supply** and **ProVision Technology Inc.**, sell and service such systems locally, as well design and install solar systems overseas. **Solar water heating** also continues to be successfully applied. An estimated 70,000 single family homes, multi-unit dwellings and institutional facilities in Hawaii are served by solar water heaters. Over 14,000 solar water heating systems have been installed under electric utility programs since 1996. Hawaii has the highest per-capita use of solar water heaters in the United States.

Terrestrial Resources

Heat from the earth, also known as **geothermal energy**, can be harnessed to produce electricity. **Puna Geothermal Venture’s** geothermal energy production facility represents an important element of Hawaii’s diverse approach to the development of alternative energy. The plant currently produces about 30 megawatts of safe, clean and reliable power. PGV employs a “**closed system**” in which deep wells are used not only to extract steam and water heated by underground lava, but also to inject the resulting condensate back into the earth and far below the water table. The steam is used to drive turbines producing power.

Looking to the Future

Future wind, wave, biomass, hydrogen, and solar energy systems will achieve steadily higher efficiencies and reliabilities as well as lower costs. Improvements in electronics and in the development of lightweight, durable materials will be integrated with improved system design. These new systems will be used by residential and business customers as well as for utility-scale electricity generation.

Clean, high-efficiency biomass combustion, gasification, methane production and other conversion technologies make the best use of available biomass, agricultural, and municipal waste. Hawaii’s long history of success in the development, design and use of these systems will serve as a strong basis for improved use of these resources.

Renewable energy technologies provide countries with opportunities to invest in the development of resources within their own borders. These resources not only provide venues for energy production but also can support aquaculture, agriculture, and a variety of scientific research projects and even eco-tourist attractions. As these possibilities become more widely recognized, integrated resource development supporting environmental preservation will become commonplace.



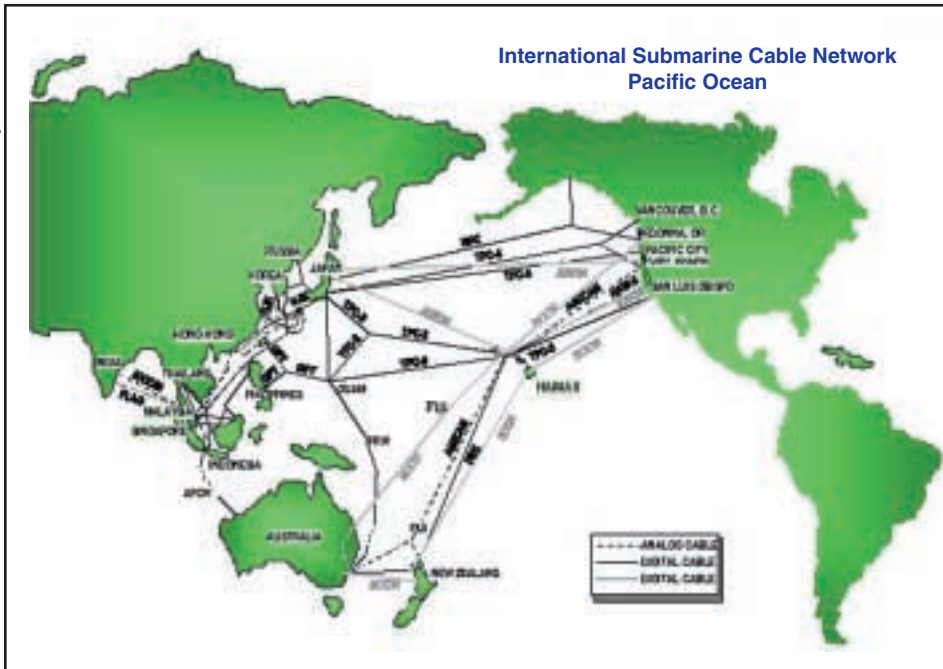
Courtesy USGS

Hawaii’s volcanic origins provide a natural and renewable source for **geothermal energy**.

TELECOMMUNICATIONS

A Diversified Hub for Trans-Pacific Satellite and Fiber Optic Networks

Courtesy Verizon Hawaii



Situated at a diversified hub of trans-Pacific fiber optic cables, satellite links and cellular and wireless networks, the State of Hawaii affords a full range of advanced digital telecommunications services to local communities as well as to all domestic and foreign destinations.

More than 40,000 strand miles of intra- and inter-island fiber optic cable link our island communities to the world. One undersea cable, a “super-carrier,” increases total capacity by 130,000 circuits and provides a separate, redundant backup for the entire fiber cable network in the Pacific. In 1998, 100% of local telephone lines were converted from analogue to digital switching. Two submarine interisland fiber-optic cable systems ensure digital connectivity and communications are available on all islands within the state.

High data rate links with more than 30 state-of-the-art telecommunications satellites complement Hawaii’s terrestrial fiber network, and provide rapid connectivity to remote locations throughout the Asia-Pacific region. Hawaii has the highest per capita use of cellular telephones in the nation, and a wide range of cell services are now provided by companies statewide. The state is ahead of the nation in Internet penetration at 65% (research by Omnitrack group, July 2000). DSL service has been increasing tremendously, with over 35 ISPs now selling service statewide. Approximately 69% of Hawaii households have a computer (compared to 50% nationwide), and two in seven Hawaii residents have made purchases on the Internet.

TRANS-PACIFIC CONNECTIVITY

Digital undersea fiber-optic cables connecting through Hawaii are facilitating simultaneous voice, data, and image transmissions to major markets in the U.S. Mainland, Canada, Japan, Korea, Hong Kong, Taiwan, Singapore, the Philippines, Australia, New Zealand, and Malaysia. In addition to exceptional bandwidth, Hawaii-based companies now have the capability to send secure data on dedicated T-1s to every major business center in Asia and Europe. A Hawaii-grown company, Digital Island, is facilitating this capability, and offers multinational corporations single-hop connectivity into both local and international Internet markets (see also *Information Technology*).

The latest broadband connections – a pair of new digital fiber transports that opened to traffic in fall of 2000 – effectively increased the available bandwidth to the islands by a factor of 40. The Southern Cross Cable Network (SCCN), providing 120 gigabits per second (Gbits/s) of capacity between Hawaii, Australia and New Zealand, is enough to transmit two-full length motion pictures every second. Southern Cross capacity between Hawaii and the U.S. Mainland is 160 Gbits/s, with a minimum of 40 Gbits/s dedicated to the Hawaiian Islands for local use. Availability is designed to exceed 99.999%, compared with an industry standard for single strand cables of 98%. The Southern Cross network is comprised of two separate cables, helping to ensure reliable access to the Internet, and will be upgraded to 240 Gbits/s

in 2002 (with potential for expansion to 480 Gbits/s). The **Japan-U.S. Cable Network (JUSCN)**, with a capacity of 80 Gbits/s (enough to carry over 900,000 simultaneous phone calls), has a projected ramp up to 640 Gbits/s by 2002. One of its first customers, the University of Hawaii, is taking ownership of more than 300 megabits of bandwidth, which has tripled its Internet access capability. Both SCCN and JUSCN are detailed in grey in the cable network diagram on the facing page.

Hawaii's state-of-the-art telecommunications infrastructure and capabilities are complemented by a progressive State regulatory framework that fosters competition in the industry, which in turn helps to keep in check the costs of telecommunications statewide. A wide variety of choices in local, interisland, national, and international telecommunication services provided by **Verizon Hawaii, AT&T, MCI, Sprint, and GST**, among others.

This extensive telecommunications capability is facilitating a broad range of applications statewide.

- ◆ **Cable television** extends to 97% of residents on Oahu, and cable franchises operate on all major islands, which can be used to support a wide variety of digital services.
- ◆ **Public education programs and inter-agency communications** are facilitated by fiber and microwave telecom networks (voice, data, video-conferencing) supported by the state.
- ◆ Internet **web page designers** and **telecommunications software** producers are well established throughout the state.
- ◆ Hawaii is also becoming increasingly known for its **advanced digital transport capabilities, data centers, and call centers**.

The Asia/Pacific region is facing unprecedented Internet growth, with e-commerce projections exceeding US\$ 1 trillion by 2004. The implementation of new high-speed global fiber optic systems connecting through Hawaii has spurred the development of **Internet data centers** and helped expand the state's role as a trans-Pacific telecommunications hub.

Data centers offer a wide range of services to businesses – from complex web and server hosting to redundant data storage for disaster recovery. Located in downtown Honolulu, **NetEnterprise** provides a wide array of data center services including dedicated Internet access, computer networking solutions, web hosting, server colocation, and communications technology expertise to organizations in Hawaii and throughout the Pacific. With headquarters in Honolulu and sales offices in Tokyo, Seoul, Taipei, Sydney, Singapore, Los Angeles and San Francisco, **Pihana Pacific** provides a world-class service portal on the Internet, maintaining a carrier-neutral Internet exchange (IX) that enables customers to interact with vendors and partners throughout its data center locations. **Mid-Pacific Broadband, Inc. (MPBI)**, a developer of broadband solution systems, has signed a lease with **Campbell Estate** to build a \$125 million Enhanced Broadband Center (EBX) containing the state's largest Internet Data Center (IDC) and first Network Access Point (NAP). The Center will be built on 54 acres of undeveloped land in Kapolei (see next page) and will offer rapid storage and retrieval, data mining and management, and ASP (application service provider) services for global enterprise-level companies. MPBI will develop a multi-level Network Attached Storage (NAS) and Storage Area Network (SAN). The NAS will be particularly useful for applications that manage their own storage, while the SAN will provide powerful, rapid, and highly-reliable data storage and retrieval.

INTERNET DATA AND CALL CENTERS

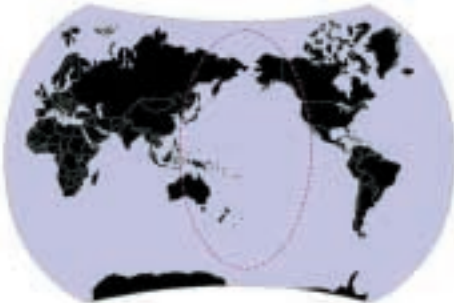


Based in Honolulu, the **Pacific Telecommunications Council (PTC)** is an international, non-profit, non-governmental membership organization that brings together both providers and users of communication services, as well as policy-makers, technologists, lawyers, engineers, researchers and educators. PTC's members are found worldwide, and membership is open to all who share an interest in the development and beneficial use of telecommunications and related disciplines in the Pacific hemisphere, including the Americas, Asia, and Oceania. The **PTC Annual Conference** is held in Hawaii each January, and provides a forum for discussing the latest telecommunications developments and issues. PTC also hosts **mid-year seminars** in different countries. These two-day events provide opportunities for interested parties to gain greater understanding of regional and domestic issues through presentations by local and international speakers.

Firms looking for an **exceptional call center site** to do business with Asia will find Hawaii to be the ideal location. The islands' mid-Pacific location allows companies to **communicate with cities such as New York, Washington, D.C., Hong Kong, Tokyo and Singapore during the same business day**. Hawaii's sophisticated fiber-optic and satellite communications networks link Hawaii to the world. Hawaii is one of the most wired states in the U.S., offering **completely digital, high-capacity voice and data transmissions and virtually limitless bandwidth**. Hawaii's ethnically-diverse workforce is known for its excellent customer service and **multilingual skills**, a natural friendliness, a strong work ethic, loyalty and dedication. The state's comparatively **low skilled labor fees**, and **progressive tax incentives** (state tax holidays; no tax on gross income derived from out-of-state contracts, or on inventory, furniture, equipment or machinery; credit granted against taxes paid on the purchase of capital) lower operational costs. **United Airlines, Genesys Conferencing, Inc., Sprint PCS, CheapTickets, Pencro, Southco, Inc., AT&T**, and others have all established regional call centers in Hawaii, and **Call Center Hawaii** (www.callcenterhawaii.com) can help companies establish new sites in the state.

EDUCATIONAL NETWORKS

Courtesy PEACESAT-SSRI/UH



PEACESAT Pacific Footprint

Established in 1996, Hawaii's **E-School** operates as a supplemental virtual school accessed via the Internet and instructional television to provide additional coursework to any student, any place at any time. Its vision is **to empower students in their use of information technology to develop marketable skills for an increasingly digital workplace environment**. Over the years, E-School has made significant strides toward promoting challenging standards that assist state-wide systemic reforms; developing curricula and teaching strategies exportable to other settings and communities; benefiting students by integrating acquired technologies into curricula to enhance teaching, training and student achievement; developing new learning environments for disadvantaged and technologically under-served students; and creating high-quality educational technology applications and services that can be marketed to other communities. Further information on E-School is available on the Web at www.eschool.k12.hi.us (see also "Education and Training" under *Information Technology*).

Hawaii also extends educational and training services via satellite to areas within the Asia-Pacific region that do not have access to fiber optic networks. The **Pan Pacific Education and Communication Experiments by Satellite (PEACESAT)**, a program of the **Telecommunications and Information Policy Group of the Social Science Research Institute, University of Hawaii**, provides **interactive video teleconferencing** to Guam, American Samoa, Commonwealth of the Northern Mariana Islands, the Federated States of Micronesia (Pohnpei, Kosrae, Chuuk, Yap), the Republic of Palau and soon the Republic of the Marshall Islands. Funded, in part, by the National Telecommunications and Information Administration of the U.S. Department of Commerce and other program partners, its activities support the development of affordable, strategic public service telecommunications for education, health care, natural disasters, economic and human resources development, and capacity building at the community, state, national and regional level. There are currently

52 PEACESAT sites in 22 Pacific Island jurisdictions which share the use of 9 simplex and 3 full-duplex narrow-band analog circuits. The simplex circuits are used for teleconferencing. The full-duplex circuits are used for point-to-point voice and 9.6 Kbps data communications. PEACESAT uses the **GOES-2 Satellite** under a Memorandum of Understanding among the U.S. National Telecommunications and Information Administration (NTIA), the National Oceanic and Atmospheric Administration (NOAA), and the National Aeronautics and Space Administration (NASA).



Located on the western coast of the island of Oahu, the **City of Kapolei** is a master-planned urban center rivaling downtown Honolulu in size. The Kapolei region encompasses the **state's largest industrial park** and second-busiest **commercial harbor**, a new **business park** and **vacation resort area**, residential developments, and telecommunications infrastructure to facilitate the Information Age. **James Campbell Industrial Park**, situated within Kapolei, is a designated **Foreign Trade Zone**. The state uses the FTZ program to promote economic development, so there are no fees or costs for companies seeking this status, and assists companies with the application process. Kapolei is also designated as an **Enterprise Zone**, enabling eligible businesses to take advantage of state excise tax exemptions and income tax credits, as well as local tax incentives (in some cases, for the first seven years of operation).

Often referred to as the "**Pacific Port of the Information Age**," Kapolei is wired, with **direct access to transpacific fiber optic cables and satellite networks** that give companies instantaneous global connections. Kapolei's telecommunications infrastructure allows private secure networks for global voice, data, and video transmissions to bridge to the mainland U.S. and Asia. This is made possible by direct fiber links to earth stations at the **Kapolei Teleport** that can "see" North America and Asia-Pacific satellites simultaneously. Companies such as **Software Pharmacy Inc.** (the only web-based company providing Internet and data warehousing for pharmaceutical claims information), **Southern Cross Cable Network** (see previous pages), **AT&T**, **Verizon Communications**, **Time Warner Telecom/Ocean Communications** (offering transport and switched services, long distance telephony, dedicated Internet services, and fiber optic ring networks), and **Vision Accomplished** (servicing domestic and international satellites with tape, studio, and fiber interconnection) have recognized the strategic advantages afforded by Kapolei's unique location and infrastructure.

Satellite telecommunications companies have also been attracted to Kapolei – especially as a site for connecting Asia and the Pacific with the United States. **Loral CyberStar**, an international satellite communications company facilitating private data networks, Internet connectivity and video transmission services, established an earth station at the Kapolei Teleport as a key part of its strategy for expansion into the region. Hawaii-based **USAsia Telecom (USAT)**, a provider of high-speed connects to the U.S. Internet backbone, established a satellite gateway at Kapolei to enable direct service to Internet Service Providers throughout Asia. **Southco, Inc.**, an international manufacturer of engineered access solutions, established its Asia-Pacific technical support, training, and computing center at Kapolei to complete its worldwide communications and customer service network. And **Transvision International (TxVision)**, a global provider of transportable and fixed teleport services, will build four satellite antennas at the Kapolei Teleport by the end of 2001, enabling the company to connect Internet services from the US via fiber to Kapolei and via satellite to two-thirds of the world's population in China, Japan, Korea, Malaysia, Indonesia, Philippines, Thailand and India.

Looking to the future, companies can easily establish **video links** between North America and Asia – opening vast markets for entertainment, news, education and television. Kapolei is also a perfect launching site for **e-Commerce** companies that want to access not only highly competitive major markets, but also yet-to-be-cultivated markets in Asia, India and other Far East countries.



Courtesy David Franzen

KAPOLEI: HAWAII'S e-CITY



Courtesy Boeing Satellite Systems, Inc.



Courtesy Gary Hofheimer

The **Kapolei Teleport** sits astride a number of **trans-Pacific fiber optic cables** and is connected to **terrestrial networks**. The Teleport also houses several **satellite earth stations** supporting eight antennas (to expand to 16 by the close of 2001). With this dynamic pairing of technologies, **Kapolei businesses** can now penetrate markets where **fiber optics is not yet available**. The Teleport's unique viewing site allows the earth stations to "see" Asian satellites that are invisible to the continental U.S., as well as North American satellites that are invisible to Asia. This overlap of satellite footprints gives U.S. businesses **rapid and direct access to large, growing markets in Asia** that are not served by fiber optic cables.

TECHNOLOGY-BASED DEVELOPMENT IN THE NEW MILLENNIUM

Building Knowledge-based Industries for Economic Growth

HAWAII'S STRATEGIC ADVANTAGES



THE HAWAII CONVENTION CENTER

The foregoing pages have displayed some of Hawaii's unique and valuable assets, which prescribe a technology development strategy based on niche opportunities where the State offers clear competitive advantages.

The following categorization of Hawaii's assets and advantages is relevant to formulation of this strategy:

- ◆ Hawaii is **an attractive place to live**, work and visit because of its pleasant subtropical weather; its natural beauty; its unique blend of Pacific, Asian and western cultures; and its reputation for hospitality and healthy living.
- ◆ Hawaii is well-positioned to serve as **a two-way economic bridge between the American and Asian markets** because of its mid-Pacific location, excellent transportation and communication services, commercial and cultural ties to both America and Asia, a legal structure that provides a safe environment for U.S. and foreign investments, and a time-zone which allows same day communication with American and Asian companies during a portion of normal working hours for all parties.
- ◆ A new, **state-of-the-art Convention Center**, proximal to hotels, businesses and recreational facilities, provides an ideal venue for hosting large, international gatherings, such as annual meetings of the Pacific Basin Economic Council and the Asian Development Bank, as well as business and professional conventions.
- ◆ Honolulu is **a major connecting node for high-capacity fiber optic cables**, thereby linking Hawaii to markets throughout the Pacific. Satellite dishes at the Kapolei Teleport "see" both Asian and North American telecommunications satellites. In addition, plans are underway for construction of the largest Internet data storage and data transit center in Hawaii to serve the Asia-Pacific region.
- ◆ Honolulu remains **a major transportation hub**, offering daily flights and timely air freight service to numerous American and Asian cities. Plans for an international air cargo center include provision for foreign trade zone and world trade center facilities.
- ◆ Hawaii's pillars of **technically-oriented research excellence and advanced research facilities** include Pacific-wide tropical agriculture, aquaculture, marine sciences and ocean engineering, alternative energy, information technology, medical research, astronomical research, geology and geophysics, and remote sensing. Its universities and federally-funded East-West Center are highly-regarded institutions in these disciplines, as well as in the social sciences, arts, and linguistics, thus forming the basis for a "globally-informed" center of knowledge.
- ◆ Hawaii sports a **skilled work force** in many areas which are important to high-tech, supported by public and private universities, colleges, community colleges, and trade schools, and buttressed with an infusion of legislative support. Graduates of the University of Hawaii's Colleges of Engineering and Business Administration have been especially sought after by information technology, telecommunications, and Asia-Pacific oriented enterprises.

- ◆ Hawaii is growing an **advanced telemedicine network** linking medical centers throughout Hawaii to remote areas throughout the Asia-Pacific region. Advanced diagnostic services are provided through a joint venture between Queen's and Kuakini Medical Centers and Mayo Medical Laboratories. As shown in a foregoing section, Hawaii is also a site for one of only a handful of Positron Emission Tomography (PET) scanners in the world, and is actively involved in 3-D medical imaging research.
- ◆ The **200-mile Exclusive Economic Zone** surrounding the Hawaiian Islands provides manifold opportunities for alternative energy testing, aquaculture development, and pharmaceutical-oriented research. It also provides clear legal access to vast living resources and mineral resources, including deposits of manganese nodules (which contain copper, nickel, cobalt and manganese) on the ocean floor.
- ◆ The state offers **technology-oriented business parks and incubator facilities**, including the Manoa Innovation Center, Maui Research and Technology Center, Mililani Technology Park, Kapolei Business Park, and the Hawaii Natural Energy Laboratory. Plans for a new UH medical school site and a world-class aquarium can transform the Kakaako portion of the Honolulu waterfront into a valuable bio-research venue.
- ◆ **Advanced digital telecommunications infrastructure development** in West Oahu's Kalaheo area, together with ample returned Navy lands, provide a practically a virgin venue for new industry investment. Through its unique mid-Pacific location, state-of-the-art infrastructure, and resident expertise, Hawaii has become a strategic node on the Information Superhighway serving the Asia-Pacific region. A variety of satellite and terrestrial networks are also supporting a broad range of applications in electronic commerce.



Infrastructure Requirements for Technology-Driven Growth

Hawaii's strategic technology-related assets well position the state to develop technology-based industries to fuel economic growth. But Hawaii must also address the need for appropriately skilled workers in order to realize the economic diversification and growth potential offered through the emergence of more advanced knowledge-based industries.

New companies and industries built around such technologies offer the prospect of attaining competitive advantages for Hawaii's economy; but without sufficient venture capital to finance such development, this potential will not be fully realized. Furthermore, in order to fulfill the promise of this technology strategy, it must be recognized that both the public and private sectors need to improve productivity, reduce regulation, and enable firms to be more competitive – both locally and overseas.

Finally, to both attract and retain new technology-based enterprise to Hawaii, as well as the skilled workers they require, it will be critical for the state to ensure that the islands' distinct attributes and quality of life – including a beautiful environment, low incidence of crime, quality of education, and other desirable characteristics – are supported and maintained.

INFRASTRUCTURE REQUIREMENTS

To meet these challenges, the Cayetano administration has focused on streamlining and restructuring State government. **Regulatory reform** – to promote productivity, allow Hawaii firms to compete better in the global market, and improve the business climate for investment – has been a high priority. Reform has meant reorienting State economic laws, regulations, and policies to reduce barriers for doing business in Hawaii, lower business costs, and develop realistic partnerships between the public and private sector for economic development. Reform also has called for legislative action to provide incentives, and challenged industry and enterprise to act more quickly and substantively to meet commitments and responsibilities implied in these incentives.

What the State is Doing to Facilitate Tech-Based Enterprise

Over the past three years, the State Legislature and Administration have undertaken a variety of initiatives to revitalize Hawaii's economy through innovative applications of technology. For example, personal and business tax cuts amounting to an estimated \$2 billion over six years have been implemented. Autonomy has been granted to enable the University of Hawaii to secure grants for cutting-edge research and participate more directly in economic development of high technology and other economic initiatives. Computer education goals have been established for public schools to create a computer literate and globally competitive workforce. And a Hawaii Tourism Authority has been established with a specific mandate to promote technology-related conferences, workshops, and exhibitions statewide.

Several legislative measures supporting the growth of Hawaii's technology sector (Acts 118, 178, 195, 237, and 297) have established a broad range of incentives for technology-based companies. Key among these include:

- ◆ Prohibition of discriminatory State-level taxes on electronic commerce or Internet access (patterned after federal law).
- ◆ High-technology business tax credits for investment in qualified high technology businesses.
- ◆ Tax credits for new or increased R&D in Hawaii. Investments in a technology business earn an income tax credit equal to 10% of the investment, up to a maximum of \$500,000. Increasing research activities also qualifies for tax credits, equivalent to an additional 2.5% of expenses over the base amount.
- ◆ A tax exemption for income received from stock options.
- ◆ Funding for the Governor's Millennium Workforce Initiative to fast-track training for highly skilled technical jobs in such industries as biotechnology, healthcare, and information technology.
- ◆ Establishment of a Governor's Special Advisor for Technology Development to help bring industry and government together in partnership for high-tech growth.
- ◆ Permitting the sale of unused net operating losses by qualified technology companies upon approval of the Tax Director.
- ◆ Adding tax exclusions for royalty income from qualified patents, copyrights and trade secrets.
- ◆ Increasing the period for capital loss carry forward to 15 years.
- ◆ General Excise Tax (G.E.T.) exemptions for Hawaii-based contractors and service business that perform services or fulfill contracts outside of Hawaii.

- ◆ New laws creating a workforce development program aimed at providing Hawaii’s workforce with technology-based skills through a cooperative program between the Department of Labor and the University of Hawaii.
- ◆ “E Academies” established by the Department of Education to teach technological, science, math and engineering subjects through “virtual” schools inside a delegated school in each district.

Updated information on Hawaii current legislation activities can be found at: www.ehawaii.gov/government/html/index.html.

A description of State administrative directives may be found in the document “**Strategic Planning for Technology-Based Development in the State of Hawaii**,” State Department of Business, Economic Development and Tourism, December 2000. In broad terms, **recommendations** contained in this report support actions to:

- ◆ Better **coordinate efforts and nurture mutually beneficial networks**, relationships, and clusters among the various parties involved with high-tech development in Hawaii.
- ◆ **Attract talent and increase research at the University** in the selected areas of excellence that will provide commercial benefits to Hawaii.
- ◆ **Foster technology transfer** of research results to commercial applications in Hawaii.
- ◆ **Upgrade workforce skills** in scientific disciplines, engineering, telecommunications, and computer science to the mutual advantage of both workers and the high-tech companies.
- ◆ **Reorient professional disciplines** such as law, accounting, corporate management, and finance to meet specialized requirements of technology-based transactions.
- ◆ **Provide physical infrastructure**, including affordable building space, land area, and telecom connections needed to achieve success with technology-based ventures.
- ◆ **Streamline regulations and provide incentives** with appropriate environmental safeguards to support more entrepreneurial activity and reduce the costs of doing business in Hawaii.
- ◆ **Strengthen marketing and promotion** of Hawaii’s technology-based products and services, and of Hawaii as a location for technology-based companies and research activities.



WORKFORCE DEVELOPMENT AND THE IMPACT OF THE UNIVERSITY OF HAWAII SYSTEM

Training Today's Youth for Tomorrow's Leaders

WORKFORCE AS AN ECONOMIC DRIVER

Education is both an important source and a product of economic growth. By increasing knowledge and flexibility instilled by the learning process, education improves the productivity of the workforce over time and expands the productive capacity of an economy.

Hawaii's workforce has been an important contributor to the state's economic growth since statehood. It more than doubled between 1959 and 1998, in part due to in-migration from other states and countries. In addition, an increasing percentage of Hawaii's labor force has graduated from college. In 1960, only nine percent of Hawaii's adult population, aged 25 and over, had a college degree; by 1998, the percentage of adults with bachelor's degrees or higher had risen to 24%.

Using growth accounting methodology, it has been estimated that higher education's effect on raising labor earning in Hawaii alone accounts for 14% of Hawaii's economic growth between 1959 and 1989. This number understates the contribution of higher education to Hawaii's economic growth, since it does not include, for example, the positive benefits of research or service provided by Hawaii's higher education institutions to local businesses and industries.

Broadening this methodology to account not only for research contributions but also for total UH-related expenditures, it has been estimated that these factors annually generate \$1.6 billion, directly and indirectly, in business sales, 29,000-plus jobs, \$1.1 billion in income to Hawaii households, and \$183 million in state and local taxes. For the second year in a row, the University has set a new record in total funding for research and higher education. During Fiscal Year 2000, UH garnered \$180.6 million in extramural grants, a 9% increase over the previous year. The biggest gains were in funding for research, where new records have been set in each of the past five years. Last year's research awards totaled \$102.8 million, up from \$92.7 million in FY 1999. Key areas of research receiving significant external support include:

- ◆ Free electron laser imaging
- ◆ Cancer and anti-tumor agent research
- ◆ Specialized neuroscience research
- ◆ Malaria vaccine development
- ◆ Marine Bioproducts development
- ◆ Oceanographic and undersea research
- ◆ Development of a autonomous underwater vehicle
- ◆ Global climate change modeling and prediction
- ◆ Astronomy/astrophysical research
- ◆ Broad band & wireless communication
- ◆ Hydrogen fuel cell development
- ◆ High energy physics research
- ◆ Tropical soil management

Several of these areas have been mentioned in previous sections of this report. We now highlight several University research initiatives with significant potential for expanding and diversifying Hawaii's economy.

Free Electron Laser Research

This technology can be used to probe the fundamental structure of matter and living organisms, or to provide electrical power to satellites and orbital transfer vehicles. Dr. John Madey's experimental success with X-ray technology in gene-protein research has been highlighted in the *Biotechnology* section of this report. In addition, another attractive application of free electron lasers (FELs) is in the area of precision cutting and drilling. The Free Electron Laser is able to make finer and more precise cuts in bone and tissue than are possible with standard surgical tools. The laser generates pulses of light intense enough to ablate (vaporize) the surface layer of whatever material the laser is focused on. The light pulse is so precise and quick that little or no thermal damage occurs to the surrounding area. Not only is the ablation precise, but it is also painless. This will ultimately facilitate surgery on the central nervous system without damaging adjacent nerves. It can also be used for removing dead tissue from burn victims and for surgery on patients where anesthesia cannot be used.

Hydrogen Fuel Cell Research

Researchers have long known the power of hydrogen as a clean, non-toxic and inexhaustible source of power. Today, hydrogen is used to propel the Space Shuttle out of earth's gravity. The major constraint to its use as a cheap and clean source of fuel for other purposes is that it is difficult to store safely in large quantities. Storage is the key to adapting hydrogen as a fuel for either cars or homes. UH chemist Craig Jensen is focusing his research on finding efficient, inexpensive methods of storing hydrogen as an energy carrier for fuel cells. In particular, he is working on the use of metallic hydrides – compounds in which hydrogen atoms are chemically bonded to metal centers such as magnesium or aluminum. Jensen's work has won key honors from the U.S. Department of Energy.

Broad Band and Wireless Communication

Recognizing the importance of wireless communications for both military and civilian use, the Department of Electrical Engineering is involved in the development of sophisticated communication systems that are easily deployed, mobile, secure, and have the ability to support a variety of different bandwidth information sources. The communication systems will be wireless networks that can accommodate different bandwidth information sources, ranging from broadband multimedia applications to sensor and control information. The development of these networks involves research in diverse areas including semiconductor devices, micro electro-mechanical systems, millimeter-wave devices, channel coding and modulation, signal processing algorithm design, and network control and optimization.

Planetary Biology

The School of Ocean and Earth Science and Technology is working to make a major contribution to bio-ecology – a rapidly emerging field that explores the role of microbes in processes related to earth and rock formation. A major question is whether microbes weaken certain parts of the earth's crust, thus influencing where fracture lines are likely to occur in an earthquake. Another area of attention is planetary biology, which explores how certain microbes can survive in extremely harsh environments. This includes the study of microbial colonies living in and around extremely hot undersea volcanic vents and in polar ice. This exciting field of investigation also includes evaluation of evidence for the possibility of life forms on other planets in the solar system.



Courtesy The Estate of James Campbell



Astronomy

Through development and operation of astronomical research and training facilities on Mauna Kea, on Haleakala, and at its Manoa and Hilo campuses, UH is expanding humankind's understanding of the physical Universe. Recent discoveries of planetary systems beyond our own solar system are among the more widely recognized achievements of the University's astronomical research program. Current and future research will focus on key questions related to how our Universe is evolving, how galaxies and the stars within them form, and how many stars contain planetary systems. Particular attention is being given to planets like Earth, where life could have developed.

Agricultural Biotechnology

The College of Tropical Agriculture and Human Resources (CTAHR) supports the expansion of diversified agriculture in Hawaii through basic and applied research to develop new and improved crops. Following the successful use of genetic engineering to develop "ring spot" virus resistant papaya, college researchers are now working on developing a nematode-resistant pineapple and on the control of the "bunch top" virus in bananas. University researchers are also involved in the development of an automated plant tissue culture facility that will focus on plant tissue cultures for elite varieties of coffee, cacao, and other tropical crops.

Marine Bioproducts

The Hawaii Marine Bioproducts Engineering Center (MarBEC) is involved in the discovery and development of new marine bioproducts. Marine environments contain a wide range of micro algae and other organisms that have tremendous potential to provide new bioproducts, including enzymes, antibiotics, anti-cancer agents, food additives, and pigments. In addition to basic and applied research, a key component of MarBEC's mission is the development of business relationships with industry partners located in Hawaii, North America and leading technology countries in the Pacific Rim and Europe.

Partnerships with Business

A major contribution of the **University of Hawaii System**, which includes its principal 4-year campuses at Manoa, Hilo, and West Oahu, as well as Community Colleges on each island, is its partnering with businesses to train workers for emerging and growing industries. For example:

- ◆ When **Continental Airlines** was deciding where to locate its new \$24 million **wide-body maintenance** facility in the Pacific, the aeronautics maintenance program at Honolulu Community College was able to supply the necessary workers, which became a major factor in Continental's decision to come to Hawaii.
- ◆ **Honolulu Community College's** new **commercial aviation program**, in partnership with the University of North Dakota, makes it possible for students to literally "reach for the sky." Students who dream of entering the booming global aviation industry can now earn their private and commercial pilot licenses in Hawaii.
- ◆ **Cisco Systems, Inc.** designated Honolulu Community College as one of its Regional Training Academies to train experts in computer networking. The academies help high school students learn how to design, build, and maintain computer networks and prepare them for entry into this fast growing field.

- ◆ **Kapiolani Community College** has partnered with local hospitals to develop Hawaii's first **Diagnostic Medical Sonography (ultrasound) training program**.
- ◆ **Hawaii Community College** on the Big Island has developed training programs to supply workers for new, emerging industries such as call centers, forestry, and awa and noni production.

The University also has established a new partnership with the business community and local government to stimulate entrepreneurship in knowledge-based industries. Known as "**University Connections**," this partnership is actively promoting innovation and commercial growth in biotechnology, healthcare, and information technology, among other areas.

In his 2001 State of the State address, Governor Benjamin Cayetano noted that "the University of Hawaii is not just a place of higher learning; it is also a driving force for the economic development of this state." This section has highlighted a variety of university-based programs and activities that underscore this fact.



Courtesy UH Relations

ISLANDS OF SUPPORT FOR TECHNOLOGY-BASED DEVELOPMENT

Providing Public and Non-Profit Service for Entrepreneurial Growth

To realize opportunities afforded by Hawaii's resources for tech-based growth, as well as to provide means for catalyzing tech-based growth and diversification, the State and its four counties have established and support economic development boards, technology parks, and incubation centers. Some, like the **Manoa Innovation Center**, were established to facilitate commercialization of university research spinoffs. Others, like the **neighbor island economic development boards**, were founded to enable development of resources in specific locales, or to facilitate extensions into commercial applications of defense or other federal dual-use technologies.

Over the years, these programs have provided essential startup support to help launch new commercial enterprise. Experience elsewhere has shown that such programs can often lead to a variety of benefits, including expanded industrial contacts, formation of research consortia, centers of excellence, industry-supported research chairs, spinoff company formation, and greater university collaboration with the external community. Furthermore, the location of particular technology industries in a given area can also generate business clustering of support industries. An industrial cluster creates demand for local suppliers who can quickly provide materials and services. Industry concentration also allows both labor and capital resources to flow more freely between firms within the region. In all, the establishment of physical locations and sustained support by state and county governments and community-based development boards provide a positive and visible focus for technology commercialization and entrepreneurship statewide.

Hawaii's Technology Support Infrastructure

This section of the report briefly describes the role and functions of key agencies that are contained within, affiliated with, or maintain close working relations with the Department of Business, Economic Development & Tourism (DBEDT), which is mandated to carry out the State's efforts to identify, promote, and market its economic development potential. These agencies are further tasked with implementing Hawaii's technology policies and with facilitating technology-based development. They include **government entities** such as DBEDT's Energy, Resources, and Technology Division, Business Development and Marketing Division, Foreign Trade Zone, the Natural Energy Laboratory of Hawaii Authority (NELHA), the Hawaii Strategic Development Corporation (HSDC), the Hawaii Community Development Authority (HCDA), and the High Technology Development Corporation (HTDC); university-based programs such as the UH Office of Technology Transfer and Economic Development (OTTED) and the University Connections Program; and community-based groups such as the four county economic development boards and the Hawaii Technology Trade Association (HTTA). The concluding section of this report describes some of the key units at the University of Hawaii which are at the forefront of research and experimentation, spinoffs from which can potentially be transferred to the private sector to enhance productivity and promote economic growth.

The Manoa Innovation Center/MIC (www.htdc.org/mic/mic.html)

Managed by the High Technology Development Corporation (HTDC - see *State-wide*), the Manoa Innovation Center is a high-tech business incubator linking emerging commercial high-tech ventures to university-oriented research and development organizations. Centrally located next to the University of Hawaii's Manoa Campus on more than three acres, the 46,000 square-foot Center brings together a diversity of enterprises. MIC's purpose is to help develop viable commercial high-tech companies in Hawaii through its incubation program. The Center also facilitates the transfer of technology and fosters joint development projects between the University of Hawaii, private, non-profit research organizations, and the Center's high-tech occupants. A variety of additional services and activities are also available to local businesses, including workshop and training, research and information retrieval, and continuing education opportunities.

Mililani Technology Park/MTP (www.planet-hawaii.com/mtp/)

Ground was broken in 1987 for the Mililani Technology Park – the only fee simple high-tech business park in Hawaii. It is zoned IMX-1 mixed-use, which allows a variety of office and light industrial uses. The Park is designated as a Foreign-Trade Zone and also has Enterprise Zone status. MTP is equipped with fiber-optic cable, providing superior communications for Park tenants. The University of Hawaii's computer network also is accessible through the Park's proteon gateway, which provides users with access to state-of-the-art and cost effective communications and data transport systems including electronic mail, R&D information sharing, and global teleconferencing. MTP has access to one of the world's most powerful supercomputer systems, the IBM Power3 and Linux Supercluster system, located at the Maui High Performance Computing Center in Kihei, Maui.

Pacific International Center for High Technology Research/PICHTR
(www.pichtr.org/)

The Pacific International Center for High Technology Research is an independent, not-for-profit organization chartered to promote and develop technology appropriate to the marine and tropical environment of the Asia-Pacific region and to assist, facilitate and support its application through technical services, education, and training. Much of its major project work has been related to the applied research and development of renewable energy technology, which is crucial to the sustainable development of the region, and for which Hawaii is uniquely qualified through its rich human and natural resources. PICHTR's programs seek to broaden Hawaii's economic base through science and technology applications such as the biomass experimentation mentioned elsewhere in this report. PICHTR also receives funding from the Government of Japan – a relationship that dates back to the summit meeting between Prime Minister Nakasone of Japan and President Reagan of the United States in 1987. As a result, Japan's Ministry of Foreign Affairs has contributed annually to PICHTR in support of the important joint United States-Japan global effort to assist the developing countries of the Asia-Pacific, as well as to develop and promote technology which meets the environmental requirements of the region.

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Kakaako Makai

Kakaako Makai (www.hcdaweb.org)

Kakaako Makai, a State-owned area along the downtown waterfront, is widely acknowledged as Honolulu's "crown jewel." It is not only an exceptional gathering place, but can also function as a center for learning, research, and economic growth. Dean Edwin Cadman visualizes the ocean-front area as the site for the new UH medical school and a biotechnology center, catering to the smaller biotech companies that have sought space near the medical facility. A high-level private sector consortium has made overtures for supportive state funding to build a new Ocean Science Education Center along with a relocated Bishop Museum Science and Technology Center in the area. At the same time, the Hawaii Community Development Authority (HCDA) is entering negotiations with Adtech, a fast-growing computer-oriented concern, for an adjacent headquarters and research facility nearby.

Kalaeloa (www.kalaeloa.com)

The return of some 2,600 acres to the State from the US Navy affords another though perhaps more distant potential for industrial growth. Much of the returned lands have been claimed by such institutions as the National Guard, the Airports Division of the Department of Transportation, and Honolulu Community College for maintenance purposes. The latter two offer opportunities for technological development. The Airports Division intends to utilize its returned facilities, which include the existing Navy airfield, as the base for operation of general aviation activity. HCC's future outlook involves extended pilot training with potential for establishment of a Pacific Aerospace Training Center. This nucleus, together with National Guard and US Coast Guard facilities, provides opportunities for aviation-related activities including depot level maintenance, aviation safety training, and advanced pilot training. In addition, the location of Kalaeloa at Barbers Point, adjacent to the Campbell Industrial Park, provides additional potential for related subsidiary or supplementary activities in the area. The Department of Hawaiian Home Lands is conducting a study to assess these possibilities.



Courtesy Airports Division/DoT



Kapolei Business Park and the City of Kapolei, located in west Oahu, is just 20 minutes from Honolulu International Airport. The Park is totally wired to support technology companies (users, providers and support facilities), call centers and other global businesses. The telecommunications infrastructure includes a multiple system of conduits traversing Kapolei, allowing private secure networks for global voice, data and video transmissions to bridge the U.S. and Asia via trans-Pacific fiber optic cables and satellite. This combination of network options is made possible by direct fiber links to earth stations at the Kapolei Teleport which can "see" North America and Asia-Pacific satellites simultaneously. A development of **The Estate of James Campbell**, Kapolei's flexible lot sizes and favorable leasing options make it well suited for expansion (see also *Telecommunications*).

Oahu Economic Development Board/OEDB (www.oedb.org)

OEDB was incorporated in 1984 to promote smart, sustainable economic development on Oahu. OEDB's long-term goal is to create quality jobs, which will in turn enhance the quality of life for Oahu's residents. Its mission is to be the driving source of collaborative leadership in sustaining a professional, globally-competitive, economic development delivery system which leverages the strengths of private and public sector partners to establish Oahu as a world-renown location to grow business, attract smart capital investment, and create quality jobs.

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Natural Energy Laboratory of Hawaii Authority/NELHA (www.nelha.org/)

Established in 1974, the Natural Energy Laboratory of Hawaii Authority, an attached agency to DBEDT/State of Hawaii, has a broad mission to develop and diversify Hawaii's economy by providing resources and facilities for energy and ocean-related research, education, and commercial activities in an environmentally sound and culturally sensitive manner. NELHA administers the Natural Energy Laboratory of Hawaii (NELH) – a unique ocean science and technology park capitalizing on the significant resources offered at Keahole Point on the Big Island, the most isolated of any coastal location in the United States, where deep ocean water is available near the shore. NELH affords tremendous research and commercial development opportunities in agriculture, aquaculture, biotechnology, chemistry, chill-intensive industries, ocean engineering, oceanography, pharmaceuticals, and renewable natural energy.

NELHA also administers two additional programs:

Hawaii Ocean Science and Technology (HOST) Park

Founded in 1984 by the State Legislature as an innovative ocean-related industrial park, HOST was the first facility in the world designed to promote and support the commercial development of ventures using deep ocean water. Today, the Park hosts the Big Island Abalone Corporation that supports a 10-acre commercial site (soon to be expanded to 70 acres) and will soon add a second tenant - Hawaii Deep Marine Water Production, which will desalinate and bottle deep sea cold water for boutique beverages and supplements.

Center of Excellence in Ocean Sciences/CEROS

The 1993 Department of Defense Appropriation Act approved and funded a National Defense Center of Excellence in Ocean Sciences to be located in the State of Hawaii. This legislation directed a cooperative effort between the Defense Advanced Research Project Agency and the High Technology Development Corporation to take advantage of unique capabilities available in Hawaii in key technology areas of interest to the Department of Defense. In September 1995, administration of the CEROS program was transferred from HTDC to NELHA. CEROS fosters technology development and commercial use of ocean research facilities in Hawaii. By encouraging participation of Hawaii companies with special expertise that may apply to DoD requirements, CEROS advances the State's goals of expanding technology-based industries. Additionally, CEROS seeks to maximize infrastructure use in Hawaii, thereby leveraging Federal research dollars and expanding efficient use of other resources. The CEROS program emphasizes private sector development by contracting with commercial entities qualified to do business in the State of Hawaii. CEROS also encourages private sector concerns to use facilities and academic expertise in Hawaii to augment capabilities and assure timely commercialization of advanced technology. University participation in CEROS projects is mainly through collaboration as subcontractors to private sector companies.

The University of Hawaii at Hilo/UHH (www.uhh.hawaii.edu)

UHH is a **regional comprehensive university** with strong programs in computer science, business, marine science, astronomy, biology, agriculture, and geology, with a proposed degree in electronic engineering. It **serves as a magnet for training, research and development in fields relating to high technology and biotechnology programs**, particularly because the Island of Hawaii is a state-wide center for laboratory-based alternative energy development, applied astronomy, and agricultural change. More than 400 acres on campus have been converted into a high-tech **University Park** supporting an impressive array of multinational tenants such as the **University of Hawaii Agricultural Complex**,

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The **Joint Astronomy Center** within University Park

Courtesy UHH



This aerial photo of the University of Hawaii-Hilo High Technology Park (foreground) shows an architect's concept of the future U.S. Pacific Basin Agricultural Research Center (PBARC) facility in its planned location, center left. A project of the U.S. Department of Agriculture Agricultural Research Service, the new PBARC headquarters will house about 38 scientists and 100 technicians on a \$50 million, multi-building, 30-acre campus. Research at PBARC focuses on the collection, evaluation, and distribution of plant germplasm; plant pathology and crop production; agricultural entomology; postharvest technology as it relates to quarantine issues; and aquaculture.

the United Kingdom-Canada-Netherlands Joint Astronomy Center, and base facilities for the Caltech Submillimeter, Gemini North, and Subaru Observatories. A 30-acre site is being developed for a \$50 million Pacific Basin Agriculture Center to be operated by the US Department of Agriculture. A base facility being developed by the Institute for Astronomy will facilitate the design and fabrication of instrumentation for all observatories atop Mauna Kea. An \$8 million Mauna Kea Astronomy Education and Interpretation Science Center to be run by UHH will feature classrooms, a science theatre, and a planetarium providing both formal and informal educational programs for both students and visitors, with direct links to the 13 Mauna Kea Observatories enabling both students and visitors to gain first hand visualization of extraterrestrial phenomena. A \$60 million Taiwan-financed Chinese Cultural Center is also under development.

Hawaii Island Economic Development Board/HIEDB (www.hiedb.org)

Hawaii Island (also known as the "Big Island") houses internationally renowned high-tech research facilities in the natural sciences, with broad bandwidth telecommunications and high performance computing capabilities. These include 13 astronomical observatories at the summit of Mauna Kea (with base facilities in Hilo and Waimea), ocean research activities at Keahole Point, Kona (at the Natural Energy Lab of Hawaii), sophisticated seismological sites throughout the island (including the Hawaii Volcanoes Observatory of the U.S. Geological Survey), a planned U.S. Pacific Basin Agricultural Research Center in Hilo, and a number of educational and training programs through the University of Hawaii at Hilo. HIEDB's mission is to advance high-tech opportunities in diversified agriculture production and processing, support additional research and commercial endeavors in the natural sciences and in academic disciplines focusing on high-technology applications, and promote a high-quality, technically-trained workforce.

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Maui Research & Technology Center/MRTC (www.mrtc.org)

Established in 1992, the Maui Research and Technology Center (MRTC) business incubation program began with four start-up companies and three anchor tenants. Today it houses 11 start-ups, three "phase-in-businesses" (established firms relocating to Maui), and eight anchor tenants. Together, these represent about 100 jobs, with more anticipated. MRTC was created by the State of Hawaii, with leadership from State Senator Mamoru Yamasaki and House Speaker Joe Souki, to encourage the development of a high-tech industry on Maui. The Maui Economic Development Board has been instrumental in advocating for such a center, and is contracted by the High Technology Development Corporation to manage it. Tenants receive many basic services which help offset some of the daunting and expensive obstacles to starting a high-tech business. Incubator services include access to local and wide areas networks for Internet connectivity and email, computer facilities with high-end graphics software and scanner, shared copier and fax, meeting facilities with video conferencing and AV equipment, and reception, phone and mail handling services. MRTC staff also offer business counseling and guidance to tenants on everything from financial matters and business plans to marketing and public relations.

Maui High Performance Computing Center/MHPCC (www.mhpcc.edu/)

The Maui High Performance Computer Center supports an IBM Power3 and Linux Supercluster system managed under a cooperative agreement between the United States Air Force Phillips Laboratory and the University of New Mexico. Ranked as one of the top computing centers in the world, MHPCC provides Department of Defense, government, private industry, and academic users, including those from Hawaii, with access to high-performance parallel computing technologies, expertise, and educational service. MHPCC is currently focusing on processing data from telescopes, satellites, radar, and other sensors, environmental and disaster modeling and battlefield simulations, and advanced technology workshops and the integration of technology into the classroom – providing an ideal environment in which to facilitate efficient and cost-effective transition from high tech research through production.

Maui Economic Development Board/MEDB (www.medb.org)

MEDB's mission is to provide leadership and vision for the responsible design and development of a strong and diversified economy. Established in 1982 as a private, 501(c)(3) nonprofit corporation, MEDB serves all of Maui County. The board works with businesses, educators, community organizations as well as county, state and federal governments to develop projects endorsed by the community. MEDB's initiatives brought to the county the Maui Research and Technology Park, the Maui Research & Technology Center, the Maui High Performance Computing Center and innovative workforce development projects such as Economic Literacy and Women In Technology. Through ongoing partnership efforts like the High Tech Maui marketing program, MEDB continues to support development of high-technology industry within Maui County, which has created more than 400 new jobs that have increased the county's tax revenue base.

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Kauai Economic Development Board/KEDB (www.kedb.com/)

Kauai is the home of the **Pacific Missile Range Facility**, the world's preeminent Testing & Evaluation and Training Range. PMRF provides T&E services from deep space to Deep Ocean and through these capabilities supports a full range of dual-use initiatives. The DoD's Ballistic Missile Defense programs, as well as NASA's Environmental Research Aircraft programs, are at the forefront of these activities. The Office of Naval Research's UESA program, as well as sensor integration and communications technologies initiatives, are indicative of the future directions of PMRF. The **Kauai Technology Center** is host to TREN Enterprises (which additionally has an R&D and materials manufacturing facility on Kauai), Textron Systems Division, Oceanit Laboratories, Solipsys Corporation and Digital Systems Resources. Phase II of the Center is under construction with a scheduled opening in early 2002. Tenants will include SAIC, XonTech, MIT-Lincoln Labs, Office of Naval Research, ORINCON, Lockheed Martin and Boeing, as well as the Kauai Sensor Integration & Communications Technologies Center. The Center provides video teleconferencing facilities for distance learning programs, as well as a Visitor Center with interactive multimedia exhibits to showcase business opportunities on Kauai as well as the

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history and culture of the island. Kauai's efforts in agribusiness and biotechnology are also achieving new heights with the completion of Pioneer Hybrid International's \$24 million R&D facility. The Kauai Economic Development Foundation focuses on developing Kauai's most important resource – its children – through technology programs such as ThinkQuest and Project EAST. Additionally, it works with the schools and community organizations on a myriad of education initiatives.

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STATEWIDE



State Department of Business, Economic Development & Tourism/DBEDT (www.hawaii.gov/dbedt)

DBEDT is the state government agency responsible for supporting the growth of Hawaii's business sector and encouraging initiatives for economic development, including the expansion of Hawaii's presence in the international marketplace. This is achieved by helping firms meet licensing and permit requirements, supporting community-based economic initiatives, providing loans and venture capital, encouraging responsible investment, and disseminating information on global business and trade opportunities. DBEDT works in partnership with the private sector to achieve its mission.

Two divisions of DBEDT are directly involved with promoting science and technology programs and activities within the state.

Energy, Resources & Technology Division/ERTD (www.state.hi.us/dbedt/ert/)

DBEDT's Energy, Resources, & Technology Division supports statewide economic development and diversification. It promotes Hawaii-based industries for the sustainable development of Hawaii's technology, energy, environment, and ocean resources. The division encourages private and public partnerships in research and in sustainable commercial development of Hawaii's resources. ERTD supports projects that demonstrate applications of technology which can contribute to economic efficiency, diversification of the economy, and marketing of Hawaii's expertise overseas. The division includes the Energy Branch, the Ocean Resources Branch, the Strategic Technology Industry Development Branch, and the Clean Hawaii Center. ERTD focuses on planning and developing technology areas such as telecommunications, energy technologies, environmental control and management, telemedicine, and other disciplines with potential for development within Hawaii and export to growth areas within the Asia-Pacific region. In addition, its Clean Hawaii Center has sought to strengthen the State's ability to export environmental products and services through the expansion of Hawaii's environmental, recycling and remanufacturing industries.

Business Development & Marketing Division

The Business Development & Marketing Division works to attract new investment to Hawaii, and to promote the export of Hawaii's goods and services

especially those in knowledge-based, telecommunications-reliant industries. The division seeks to direct new investment into job-creating industries that help diversify Hawaii's economy. Examples include healthcare, telemedicine, assisted care, biotechnology, aquaculture, and other nontourism-related businesses. The division's marketing activities — including business missions and seminars — are focused on overseas audiences. The division also serves as the Department's outreach to the Neighbor Islands in a number of cooperative market ventures. These include working with the Kauai Economic Development Board to promote expanded use of the Pacific Missile Range Facility, the Maui Economic Development Board to attract new activities and conferences related to Maui's High Performance Computing Center, and the Hawaii Island Economic Development Board to promote the science and technology-related capabilities of the Big Island.

The High Technology Development Corporation/HTDC (www.htdc.org)

Administratively attached to DBEDT, **HTDC** was established in 1983 by the Hawaii State Legislature to facilitate the development and growth of Hawaii's commercial high technology industry, as well as to increase revenue generation and job creation within the technology-based sector of Hawaii's economy. It facilitates growth of Hawaii's high technology industry by serving as a **one-stop informational center for technology start ups and out-of-state entrepreneurs**. It developed and manages the **Manoa Innovation Center** and the **Maui Research & Technology Center**, both full-service incubation facilities, and provides training, programs, workshops, business consulting, and shared office services to create a "success environment." It developed and supports "**TECH JOBS HAWAII**" — a public-private partnership created to raise awareness of the breadth of high technology job opportunities in the state. HTDC has conducted job fairs both in Hawaii and on the Mainland (see www.techjobshawaii.org), as well as outreach programs to demonstrate high tech opportunities at Hawaii schools. The Corporation recently launched the **Governor's E-Commerce Awareness Campaign** to encourage and educate small businesses on the advantages of using e-commerce in their business operations (a Getting Started tutorial and a list of service providers is available at www.pacificbusiness.com/exchange). HTDC also supports community outreach activities by facilitating the establishments of community technology centers, such as the **Laupahoehoe Teleservice/Telework Center** established as a training and incubation facility for new technology-based businesses in remote areas. It conducts **biennial surveys** to provide a comprehensive picture of the technology industry in Hawaii (see the **Technology Business Directory** at www.htdc.org). It secures and administers federal and local grants to encourage technology research and assist technology start-up programs, such as the **Hawaii Small Business Innovation Research Grant Program**, which provides tech-based companies up to \$25,000 for research done in Hawaii. It also helped secure a \$10 million grant from the Advanced Research Projects Agency/DoD to support two federal dual-use programs — the **National Defense Center of Excellence for Research in Ocean Sciences** and the **Hawaii Electric Vehicle Demonstration Project**. Finally, HTDC maintains an **extensive marketing program**, including advertisements and editorial placements in local and national publications; support for technology-focused seminars and conferences; special events targeting key audiences; the creation and distribution of statewide technology marketing collateral; and familiarization tours and one-on-one meetings with out-of-state high-tech corporations.

The Hawaii Technology Trade Association/HTTA (www.htta.org)

HTTA is a statewide, private-sector membership organization formed specifically to support Hawaii's growing technology industry. HTTA industry members



The Hawaii Strategic Development Corporation is a State agency created by the legislature in 1990 to promote economic development and diversification in conjunction with private enterprise. Its mission is to provide venture capital to businesses in order to stimulate economic growth, employment, and economic diversification. This is achieved through the investment of public and private funds in return for equity or ownership positions in emerging businesses. Emphasis is given to investment opportunities which further technological innovation, though almost all industry sectors are eligible for financing. Examples of industry sectors receiving venture funding include biotechnology, software and multimedia development, aquaculture, food and beverage processing and distribution, telecommunications, and medical technology. Additional information on HSDC is available at www.htdc.org/hsdc.



represent a variety of technology sectors, including Information Technology, Telecommunications, Software, Biotechnology, Health & Medical Technology and Ocean/Earth/Space Sciences, and also include professional services and educational organizations that actively support Hawaii's technology industry. Membership is statewide, with representatives from Hawaii, Kauai, Maui, as well as Oahu. HTTA's mission is **to grow the technology industry in Hawaii by fostering and facilitating a healthy business, funding, educational and governmental environment for Hawaii's technology companies**. Its focus is on promoting the local development of technology-related businesses, as well as on encouraging more mainland and international technology companies to establish a presence in Hawaii.

The University of Hawaii (www.hawaii.edu)

The University of Hawaii supports diverse science and technologies activities through a number of research units.

Institute for Astronomy (IfA) - Founded in 1967, the Institute conducts investigations in astrophysics and planetary science and is responsible for managing the Mauna Kea Science Reserve and the Haleakala High Altitude Observatory Site. It also operates solar and laser-ranging facilities on Haleakala and several observatories on Mauna Kea. IfA is one of the world's leading astronomical research centers. Its broad-based program includes studies of the sun, planets, and stars, as well as research on interstellar matter and galaxies. University astronomers are allotted observing time on all telescopes.

Cancer Research Center of Hawaii - The Cancer Research Center of Hawaii is a multidisciplinary research institute of the University. It is engaged in research on all aspects of cancer, from etiology and prevention to treatment and continuing care. In addition to conducting fundamental research in cancer biology, the center also provides training opportunities for MS and PhD students enrolled in academic disciplines closely aligned to the staff's research interests. The center is organized into three programs: (1) cancer etiology with epidemiology and molecular carcinogenesis components; (2) cancer prevention and control with medical science and social science components; and (3) in partnership with the Department of Chemistry, research on natural products with medicinal chemistry and experimental pharmacology components.

Curriculum Research & Development Group (CRDG) - The Curriculum Research & Development Group is the organized research unit in the University of Hawaii that gives attention to the functions of elementary and secondary education in Hawaii and elsewhere in the University's service area. The CRDG's function is to examine the total scholarship of the universe of knowledge and to adapt selected parts of it for use in elementary and secondary schools. The primary areas of focus are secondary school mathematics, science and technology; health; composition and language study; the history of Hawaii; language and linguistics; literature of Asian and Pacific peoples; marine science and technology; music for elementary schools; nutrition for people of Hawaii and other Pacific communities; and education for at-risk students.

University of Hawaii Economic Research Organization - The University of Hawaii Economic Research Organization maintains information for making economic forecasts, models, simulations, and policy analyses. The information is intended to aid public and private sectors in business-related decision-making. For Hawaii, projects include analyzing government spending, tax, and regulatory policies, as well as proposals to develop or attract new industries or corporations to the state. For Asia, projects focus on the potential effects of proposed public sector investments and government policies, as well as trends in international trade and investment. Links between Hawaii and Asia-Pacific economies are also being identified, modeled, and measured.

Globalization Research Center - The Globalization Research Center was established at UH in 1998 with a \$1 million plus grant from the U.S. Department of Education. The Center's mission is to conduct research on the dynamics and effects of globalization with a particular emphasis on impacts within the Asia and Pacific region. The center has developed three core research areas: (1) development of a globalization index with associated mapping of country and regional impacts, (2) creation of a globalization curriculum; and (3) the study of health issues in a global context.

Harold L. Lyon Arboretum - The Lyon Arboretum facilitates and conducts research, instruction, and public service in tropical biology and horticulture. Located on the 194-acre site in upper Manoa Valley are greenhouses, laboratories, classrooms, and an herbarium. The arboretum also houses living plant collections, comprising about 476,000 species, varieties, and cultivars. It is the only university arboretum in the U.S. located in a tropical rainforest and has perhaps the largest collection of palms of any botanical garden in the world. Emphasis is placed on native Hawaiian plants, including research on propagation and restoration of endangered species, on restoration of Hawaiian ecosystems, and on ethnobotany of the Hawaiian Islands.

Institute for Biogenesis Research (IBR) - The new Institute for Biogenesis Research at the University of Hawaii John A. Burns School of Medicine houses state-of-the-art equipment and facilities to further the research that led to the birth of Cumulina, the world's first mouse clone, in 1998. Over the last two years, continued research has produced the much-photographed green mice and significant improvements in mice cloning success rates. Currently, Dr. Ryuzo Yanagimachi and other researchers are involved in genetic research focused on curing infertility and on predicting and preventing hereditary diseases.

National Foreign Language Research Center (NFLRC) - The National Foreign Language Research Center at the University of Hawaii is one of three such centers in the nation, funded by a grant from the U.S. Department of Education. Building on institutional strengths in foreign language teaching, applied linguistics, and second language acquisition, the NFLRC undertakes projects that focus primarily on the less commonly taught languages of East Asia, Southeast Asia, and the Pacific. The goal is to develop prototypes that can be applied broadly to improve foreign language education nationally.

Office of Technology Transfer & Economic Development (OTTED) - OTTED promotes the transfer of University technology to the community and is responsible for managing UH intellectual property assets. It licenses University discoveries to industry for society's use and benefit, and works with legal counsel to patent and protect them. OTTED seeks to turn scientific progress into tangible products, encourages faculty inventorship and entrepreneurial activities, supports State economic development and diversification, and generates income to support further research and development.

Pacific Biomedical Research Center (PBRC) - The mission of the Pacific Biomedical Research Center at the University of Hawaii is to encourage and foster research in diverse fields of biology and medicine. The research programs undertaken by PBRC scientists range from basic studies of biological function to hospital clinical trials. PBRC researchers also provide training for graduate and undergraduate students, with a special emphasis on minority research opportunities. PBRC facilities include: the Bekesy Laboratory of Neurobiology, Center for Conservation Research and Training, Kewalo Marine Laboratory, Laboratory of Matrix Pathobiology, and the Membrane Biology Laboratory.



Courtesy EWC

Located in Honolulu adjacent to the University of Hawaii, the **East-West Center (EWC)** is an internationally recognized education and research organization established by the U.S. Congress to strengthen understanding and relations between the United States and the countries of the Asia-Pacific region. As part of its mission, EWC conducts multidisciplinary research on issues of contemporary significance to Asia, the Pacific and the United States – including programs in such areas as national economic development, ecosystem governance, trans-boundary and urban air pollution, population, and health.



Students examine remote sensing images to compare to their direct observations during an **undergraduate course in remote sensing**. The course was developed and is funded by Hawaii Space Grant College under SOEST at the University of Hawaii.



The **Hawaii Space Grant Consortium** program, operated for the University of Hawaii by Planetary Geosciences of the Hawaii Institute of Geophysics and Planetology, SOEST, runs **FUTURE FLIGHT** - a K-12 education project providing residential, day exploration and family programs focusing on specific "mission themes" including Apollo: the Next Generation - Return to the Moon; International Mission to Mars; and Millennium Mission to the Blue Planet. Pictured above, students "take flight" with aerodynamics designs developed during their "hands-on" training at Future Flight.

School of Ocean & Earth Science & Technology (SOEST) - Established by the University in 1988, SOEST was created as a multidisciplinary school combining academic departments and research institutes into a new structure embracing several research centers and institutes: the **Hawaii Center for Volcanology (HCV)** studies volcanoes in Hawaii and elsewhere in the world and on other bodies around the solar system; the **Hawaii Institute of Geophysics and Planetology** supports programs focusing on global remote sensing of Earth, planets, moons, and asteroids, and develops leading educational programs through administration of the Hawaii Space Grant College Program; the **Hawaii Institute of Marine Biology (HIMB)** supports research in coral physiology and coral reef ecology, behavior and population dynamics of fishes, marine endocrinology and aquaculture, and marine mammal research; the **Hawaii Mapping Research Group (HMRG)** develops and operates wide-sonar undersea mapping equipment and conducts underwater mapping surveying expeditions all over the world; the **Hawaii Natural Energy Institute (HNEI)** researches alternatives to fossil fuels, supporting ocean resource development and biomass research directed at technologies suitable for converting biomass to electrical energy, as well as a long-range program focused on the production and storage of hydrogen; the **Hawaii Undersea Research Laboratory (HURL)** studies deep-water marine processes in the Pacific, focusing on deep-sea geology and ecosystems and their contribution to global climatic and ecosystem changes; the **International Pacific Research Center (IPRC)** provides an international research environment dedicated to improving understanding of the nature and predictability of climate variability in the Asia-Pacific region, including the influences of global environmental change; the **Joint Institute for Marine and Atmospheric Research (JIMAR)** facilitates cooperation between UH and NOAA scientists on problems of mutual interest including tsunamis, equatorial oceanography, climate, tropical meteorology, and fisheries oceanography; and the **Satellite Oceanography Laboratory** provides satellite images and other real-time meteorological and oceanographic data covering hurricanes, ocean eddies and volcanic eruptions.

Social Science Research Institute (SSRI) - The Social Science Research Institute facilitates and supports applied interdisciplinary research addressing critical social, economic, and environmental problems in Hawaii and the Asia Pacific region. Research projects are carried out in collaboration with other educational research institutions, federal, state, and county agencies, and with international organizations and the private sector. SSRI provides practical experience to students at the University of Hawaii through involvement in research, planning and training projects.

Waikiki Aquarium - The Waikiki Aquarium displays more than 1,000 specimens representing 250 vertebrate and invertebrate species. The exhibits focus primarily on marine life and feature a hands-on experience with the "Edge of the Reef" outdoor exhibit. The aquarium also offers a marine education program with classes, workshops, school tours, and lecture series on marine science. Research activities include mahimahi larval studies and the reproduction of the chambered nautilus.

Water Resources Research Center (WRRC) - Established to coordinate and conduct research to identify, characterize and quantify water/environmental related problems in Hawaii, WRRC makes recommendations to all agencies and organizations with responsibilities to manage water and environmental resources statewide. It also assists Pacific Island governments in managing their water and environmental problems. WRRC faculty are specialists in marine biology, environmental and process engineering, public health, water quality microbiology, economics, ecology and environmental science hydrology, geology and geophysics, agriculture and resource management.



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