Space Product Development

Improve the Economy Here...

Extend Commerce There...

Create Opportunities Beyond...

2002 Annual Report

INTRODUCTION

Commercial development of the space frontier is one of the greatest opportunities facing the American business community. It is the growth of business into space that will bring the benefits of space down to Earth and enrich the everyday lives of all Americans.

NASA encourages businesses to seize this opportunity through the Space Product Development Program and its Research Partnership Centers (RPCs). Our goal is to enable NASA's space missions through the development of space commerce.

Space commercialization efforts spearheaded through the program have already resulted in commercially available products, and have laid the groundwork for future industries such as private space platforms and launch services. Commercial space and microgravity research has been involved in everything from helping to improve cast automotive parts for Ford Motor Company, to facilitating the discovery of a new "space rose" scent now being used in Zen perfume from Shiseido. Light Emitting Diodes (LEDs), originally developed by Quantum Devices, Inc. for commercial plant growth research in space, are now used in medical applications ranging from treating cancer to accelerating the healing of wounds. Water purification products from WTC/PentaPure, Inc. have benefited from research on the Space Shuttle, and are now being provided on an exclusive basis to Katadyn for use in it's Exstream (U.S.) and Katadyn (world-wide) sport water bottles.

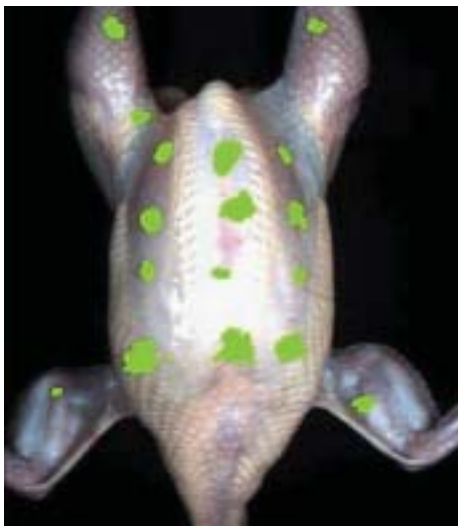
Advanced electronics research is providing advances ranging from high-temperature superconducting wire for use in power transformers, to a special optical detector that may offer the hope of sight to many people with retinal eye problems. Other commercial research is helping produce new bone replacement materials that will be stronger and longer lasting than current replacements. Advanced research in this area may even lead to a replacement that will dissolve as natural bone grows back. Pharmaceutical companies are utilizing commercial space and microgravity research to design new, more effective drugs that have fewer side effects, while exploring ways to improve drug production and reduce costs on Earth.

As a result of these and other successful efforts, commercial space and microgravity research reaches across every facet of today's marketplace. From research and development of new and improved materials to the rich fields of agribusiness, this research is helping American businesses maintain a competitive edge. In the pages that follow, you will see some of the results and opportunities that await U.S. industry and learn how space can make your business truly out of this world.

Successes

BioServe Space Technologies successfully flew its newly designed Multiple Orbital Bioreactor with Instrumentation and Automated Sampling (MOBIAS) unit within its Commercial Generic Bioprocessing Apparatus (CGBA) on board the International Space Station. MOBIAS, a fed batch bioreactor, enabled the most recent collaborative project between BioServe and its commercial affiliate Bristol-Myers Squibb examining long duration antibiotic fermentation in space.

Recent studies at the **Center for Commercial Applications of Combustion in Space (CCACS)** have found that the presence of SiO2, TiO2, and Al2O3 appear to enhance the formation of a hydroxyapatite film on a tri-calcium phosphate substrate placed in a simulated body fluid, while the lack of such constituents, or the presence of a more reactive component (MgO), appear to inhibit the formation of such a layer. These results are important for understanding how a calcium-phosphate material like those now being synthesized routinely in CCACS, becomes integrated with the natural bone structure, and they provide guidance for the design of biodegradable implants.

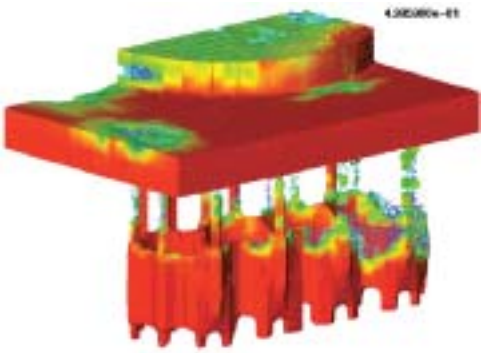


Researchers at **ProVision Technologies (PVT)** and the U.S. Department of Agriculture collaborated to develop a method of optically inspecting the world's poultry supply at the processor level. The patent-pending technology is based on results of research performed using PVT's patented hyperspectral imaging system and has been licensed to one of the worlds largest poultry processing equipment manufacturers.

Taconic Farms, Inc., of Germantown, NY is a new Associate Member of **BioServe** and is the leader in commercial production and worldwide distribution of transgenic rodent models used in basic research, drug discovery and safety testing protocols. BioServe affiliate, Dr. Stephen Keith Chapes at Kansas State University, developed a knockout mouse model that can provide researchers with a beneficial tool for testing AIDS drugs, HIV vaccines and other respiratory drug treatments. Taconic bred the transgenic mouse model through its Emerging Models Program for Kansas State University.

Solidification Design Center (SDC) industry partner, Stahlschmidt & Maiworm USA, broke ground on a new foundry facility to develop and operate the most advanced alloy wheel manufacturing facility in the U.S. The location of Auburn, Alabama was chosen so that the facility would be in close physical proximity to the SDC.

Researchers at SDC have determined the thermophysical properties of three new magnesium alloys under consideration for next generation, lightweight automobiles. The data will accelerate the product development process and enable manufacturers to optimize their manufacturing processes.



Ashland Specialty Chemical Company (Columbus, OH) negotiated with SDC industry partner ARENA, LLC of Albuquerque, NM (formerly Flow Simulation Services Inc.) to become the exclusive, worldwide distributor of the Arena-flow™ software for sand core engineering. The software is currently being used by GM, Caterpillar, International Harvester, and other premier manufacturing organizations.

Auburn University, host univeristy of the Solidification Design Center, was approved for membership in the Foundry Educational Foundation (FEF), a non-profit foundation focused on building unique partnerships among colleges and industry to develop the next generation of leaders in the foundry industry. Membership in the FEF enables educational components of the SDC's space research and development to be shared with 31 other FEF member schools and their students.

Case Studies

Biotechnology: Options in Osteoporosis Treatment

Challenge

Developing more effective treatment options for people with osteoporosis and low bone density and mitigating space flight-induced bone loss in astronauts.

Importance

Osteoporosis and low bone density are a major health threat for almost 44 million Americans aged 50 and older, a representation of 55% of this age population. It is estimated this figure will rise to over 61 million by 2020. This disease is responsible for national direct expenditures of approximately $47 million each day or $17 billion total in 2001. In addition, until an effective mitigation for bone loss that occurs as a result of human space flight can be found, long-term manned space missions will be limited.

Solution

Develop a low risk, highly effective treatment. Utilize microgravity as an accelerated bone loss test model for evaluating candidate pharmaceutical countermeasures. Osteoprotegerin is a naturally occurring protein discovered by Amgen and being developed as a treatment for osteoporosis. Amgen and BioServe conducted a collaborative research experiment onboard STS-108 to examine the effectiveness of OPG in inhibiting bone loss in mice. Preliminary results are positive.

Benefit

Provide a means for millions of aging Americans to live longer, more productive lives and reduce health care costs associated with this disease. Provide a simple yet effective tool for mitigating bone loss during long duration space flight.

Medical Systems: Improved Treatment for Eye Disease

Challenge

While extremely useful in the treatment of severe eye disease, conventional laser therapy is often associated with undesirable, and frequently severe, side effects. New, more selective, techniques using infrared lasers offer the potential for improved patient outcome compared with current laser surgery. The challenge is one of properly optimizing laser dosimetry in order to achieve full potential benefit for each patient.

Importance

The incidence of severe eye disease is increasing with the increasing age of the world population. Advanced laser treatments are now becoming available in eye centers worldwide.

Solution

Provision Technologies is working with IRIDEX, a major manufacturer of ophthalmic laser systems, to optimize the laser delivery to treat diseases of the retina.

Benefit

Ophthalmic laser surgery will be more beneficial to more patients than ever before.

Agriculture: Crop Production Technologies and Value-added Space Soybeans

Challenge

To demonstrate the performance and robust nature of controlled environment technologies developed by the Wisconsin Center for Space Automation and Robotics (WCSAR) for the production of crops in space.

To determine whether the microgravity environment may alter chemicals of commercial interest (phyto-nutrients) found in soybean seeds produced in space.

To determine whether the altered phyto-chemicals are genetically stable so that space-harvested seeds can produce multiple generations of value-added/enriched soybean crops on earth.

Importance

Soybeans are the largest single source of protein and oil in the American diet. The U.S. soybean crop yield was 2.9 billion bushels in 2002, and is projected to be 3.2 billion bushels this year (2003). Soybeans and soy-products represent $19 billion market share in the food, nutrient supplement, and feed industries. Development of value-added or value-enriched soybean varieties will have significant economic impact.

Plant life support technologies for the production of soybeans in space can also be used for the production of vegetable crops to support/sustain long-term human presence in space.

Solution

WCSAR, specializing in controlled environment technologies for plant/crop production, is collaborating with DuPont, a world leading soybean seed company, in the development of value-added and value-enriched soybean varieties. DuPont and WCSAR have conducted the first soybean seed-to-seed production experiment on board the International Space Station (ISS) during the UF-2 and 9A missions. This experiment was to investigate the microgravity-environment effects on the commercially valuable hytochemicals of soybean seeds produced in space.

Benefit

This investigation could lead to the development of unique phyto-nutrients in soybean seeds, which would have significant economic impact.

This investigation will help pave the way for the production of vegetable crops in space to sustain long-term human presence in space.

Advanced Materials: Advancing the Technology of Biodegradable Bone Implants

Challenge

To create a biodegradable bone implant that can be synthesized on-site in near-net shape form.

Importance

The world annual market for bone implants is approximately $30 billion. There are 500,000 hip implants each year in the U.S. alone. Conventional implants typically wear out or loosen over time, necessitating replacement, with the attendant costs and patient discomfort.

Solution

Porous, biodegradable, ceramics hold the promise of rapid bone in-growth, temporary strength and ultimate disappearance as the bone fully heals. Research at the Center for Commercial Applications of Combustion in Space (CCACS) has established that biodegradable ceramic materials for such implants can be produced by a process known as combustion synthesis. In this process, fine powders of an appropriate composition, ignited in a pure Argon atmosphere, undergo exothermic reactions that propagate a combustion wave through the reactant mixture, creating a new material. CCACS was the first to produce tri-calcium phosphate, Ca3 (PO4) 2, by this method. Patents are pending on several aspects of the process. During the past year CCACS has tested this material in simulated body fluids to study the chemical reactions that will occur when the material is in contact with natural bone and to look for evidence of leaching of any of the implant constituents. CCACS has observed the formation of hydroxyapatite, a major component of natural bone, on the surfaces of some of the samples having been exposed to the simulated body fluids (see figures). Results of this research have been submitted to the Orthopedic Research Society for publication.

Benefit

Using combustion synthesis of starting powders packed into molds, near-net shape bone implants are possible. The molds could be made on-site, either from impressions taken in the damaged bone areas or from digital images created from CT-scans using existing rapid-prototyping techniques. These processes would make possible individual custom-designed bone implants of biodegradable materials using combustion synthesis. The benefits of such a development would be enormous.

Figure 1. TiO2 – doped Ca3 (PO4) 2 produced by combustion synthesis.

Figure 2. Globular clusters of hydroxyapatite uniformly spread over surface of sample shown in Fig. 1, after exposure to simulated body fluid.

Implants, made of materials which are much like natural bone, would need minimal fitting and adjustment, would provide strength while the bone heals, and then reabsorb into the natural bone over time. Patients with insufficient or mutilated bone as a result of pre-existing conditions or numerous surgical procedures will have available custom designed and manufactured implants with bone-regenerating capacities at relatively low cost. A direct outgrowth of these developments would be in-vivo bone tissue engineering. Additional benefits include the use of the materials as in-vitro scaffolds to regenerate the patient's own bone material for re-implantation purposes.

Electronics/Power: High Temperature Multilayer Ceramic Capacitor Technology

Challenge

Lack of stable high-temperature capacitors for the extreme environments encountered in many space and military applications.

Importance

Conceptually, perhaps the simplest of components, and present in all electronic systems, the capacitor stores and modulates power. As circuitry becomes more complex, using higher frequencies and finding ever more demanding applications, the durability and precision of capacitors has become crucial, and in many cases the current state of the technology has become an inhibiting design factor.

Solution

The Texas Center for Superconductivity and Advanced Materials (TcSAM) has developed extraordinarily stable and rugged capacitor material based on thin film nitride deposition. Armed with this Multilayer Ceramic Capacitor (MLCC) technology, a TcSAM spin-off company, Integrated Micro Sensors, Inc. (IMS), has teamed with Raytheon and Lockheed Martin in an effort to design and deliver devices that will directly impact current and future space and military needs. To broaden the potential impact, IMS has also established commercially driven collaborations with Texas Components Corporation (a Honeywell subsidiary) and Extreme Devices, Inc. (Austin, Texas) to bring MLCC technology to market.

Benefit

The availability of high temperature MLCC frees designers to address applications in a variety of extreme environments, from down-hole pressure monitoring in the oil field to deep space power management. The prospect of integrating high efficiency solar cells (also developed at TcSAM) with MLCC materials on the same substrate points toward a dual use technology with vast terrestrial and space markets.

COMMUNICATIONS: SATELLITE COMMUNICATION NETWORKS

CHALLENGE

Develop, implement and validate scalable, secure and reliable multimedia Internet-like services using new broadband satellites in the Ka band, like the HNS Space-Way, that can interoperate with terrestrial networks, to millions of users and NASA missions.

IMPORTANCE

Key to sustained leadership of US satellite and wireless communication industry world-wide, and essential for the new wave of broadband wireless Internet technologies. Fundamental to broadband communications for NASA, space missions, and the International Space Station (ISS).

SOLUTION

The Center for Satellite and Hybrid Communication Networks (CSHCN) results involved in the solution include: media access control (MAC) schemes for two-way satellite communications, hybrid gateway for Internet via satellite, space-friendly Internet applications (HTTP), reliable and secure satellite multi-cast schemes, dynamic power allocation schemes to combat rain attenuation, intelligent monitoring schemes for very large broadband satellite networks, layered IPSEC for security.

BENEFIT

Working closely with CSHCN, HNS has maintained leadership worldwide on Internet service provisioning over satellites, has expanded markets to all parts of the world, and is moving to the new era of fast Internet over world-wide Ka-band satellites. Application markets have expanded to education. Attracting and hiring of many outstanding students by HNS, which has enabled a fast and sustainable technology transfer path and rapid commercialization. Applications of resulting technological base to NASA missions.

BioServe Space Technologies

BioServe Space Technologies (BioServe), located at the University of Colorado in Boulder, specializes in commercial life sciences research and space flight hardware design in the areas of biomedicine, biotechnology, and agriculture. BioServe, in collaboration with its industry partners, conducts both ground based and space based applied research designed to result in commercially viable products for use on Earth. Current projects are focused on developing new drug compounds for cancer, diabetes, and high cholesterol, antibiotic fermentation for improved antibiotic production, countermeasures for bone loss, plant lignin biosynthesis and cell wall biogenesis, improved mammalian cell culturing techniques, air and water purification products and plant genomics. In conjunction with its primary commercial tasks, the Center also supports and educates undergraduate and graduate students in the areas of life science and bioastronautics research, aerospace engineering, space flight hardware development, and mission operations and integration. These experiences continue to provide graduates with a competitive advantage in the market place over their colleagues. This year seven BioServe students graduated with a Bachelor's degree, eight with a Master's degree, and one with a Ph.D.

During 2002, BioServe once again demonstrated its unique capabilities as a research partnership center. By year-end, the Center completed its 22nd commercial space research mission in just over 10 years. This major milestone was reached through the expertise, dedication, and efficiency of the Center's staff of engineers, life scientists, students, administrators, business and marketing personnel, and commercial partners. BioServe displayed an impressive level of efficiency and success in hardware design and commercial space research. In FY02, the Center's engineering team designed and built five complex pieces of flight hardware that enabled the completion of five commercially sponsored flight research projects, including two space station experiments and three space shuttle experiments. The business and marketing team recruited seven new commercial partners and attended five conferences to showcase ongoing research and development opportunities to potential new customers.

Summary of Current Commercial Space Research

BioServe's commercial space research program was very productive this year with two missions accomplished. The first flight onboard STS-108, in collaboration with Amgen, Inc., examined the effects of an Amgen discovered protein, Osteoprotegerin, on reducing the bone loss that occurs while in space. This protein is being developed by Amgen to treat osteoporosis, a major health threat in over 28 million Americans.

The second mission, an extended duration antibiotic fermentation research experiment conducted in collaboration with BioServe's long time partner Bristol-Myers Squibb (BMS), flew successfully on board the International Space Station (ISS) Stage 8A. BioServe and BMS are currently analyzing samples to determine the mechanism/s behind previously observed increases in production of antibiotics produced in space. Understanding these mechanisms may improve the efficiency of Earth based fermentation facilities and thereby reduce the production costs of manufacturing antibiotics.

Supporting NASA's Mission

Ways in which BioServe supports NASA's mission include, but are not limited to, the following:

To Understand and Protect Our Home Planet

Lignin Consortium - Terrestrial applications are improved forestry and crop yields and byproducts such as reduced industrial pollution and energy usage.

Mammalian cell culture – The use of mammalian cell cultures spans a wide range of markets including pharmaceutical discovery applications, medical devices, and bio-pharmaceutical manufacturing.

To Explore the Universe and Search for Life

Osteoprotegerin – During previous space-flight research, low gravity was shown to be an excellent skeletal disuse model because it induced a more systematic and complete skeletal unloading than is currently achievable on Earth. Bone loss in space occurs at a rate of 6-24% per year, compared to 2-3% per year on Earth. This skeletal disuse model is being used to examine the effects of Osteoprotegerin (OPG) on skeletal systems. OPG can directly benefit NASA's goal of long-term space exploration by countering the deteriorating effects of space on the human skeleton, while helping 10 million Americans diagnosed with osteoporosis and another 18 million at risk (www.nof.org).

Lignin consortium – Supports NASA's goal of space exploration through the development of more-digestible, space grown food to support long-term human presence in space.

Biofilms – Studies of increased proliferation of certain strains of bacteria when exposed to microgravity for closed environment systems and terrestrial applications.

To Inspire the Next Generation of Explorers

Support education outreach initiatives including the Space Technology and Research Students (STARS™) Program for young students in math, science, and engineering.

Donated space hardware to Smithsonian Institution with plans to donate additional space hardware to Denver Museum of Nature and Science Traveling Exhibit.

"The excellent logistical and technical support provided by BioServe was instrumental in allowing Amgen to test a novel experimental osteoporosis drug in the extreme environment of microgravity. It is difficult to imagine how an experiment like this could have occurred without the professional interface with NASA that was provided by BioServe." Paul Kostenuik, Ph.D., Research Scientist, Amgen Inc.

"Taconic is a forward looking company that seeks innovative and cutting-edge opportunities. Having worked with NASA previously, our organization is enthusiastic about our new partnership with BioServe." Donna Gulezian, Product Manager, Taconic Transgenic Division.

Center for Advanced Microgravity Materials Processing

The Center for Advanced Microgravity Materials Processing's (CAMMP) mission is to develop industrial interest in microgravity, to produce products from microgravity, and establish an understanding of how microgravity is used to improve or enhance materials and their processing on Earth. The target areas are smart materials, advanced materials for sensor application, advanced materials used as detectors, and materials used as storage medium, catalysts and absorbents targeted to the chemical process industry. Industry directs the research and development activities based on potential product discovery, improvement, and development.

Summary of Current Commercial Space Research

In FY02, CAMMP processed two solution crystal growth experiments onboard the International Space Station (ISS) Stages 8A andUF-2. Each experiment was accomplished in the US Laboratory utilizing the Zeolite Crystal Growth (ZCG) Furnace hardware.

On mission 8A (STS-110), CAMMP successfully demonstrated the operation of new ZCG Assembly hardware including an improved FU furnace unit and computer-based IZECS control system. During on orbit experiments, 19 separate crystal growth experiments were automatically processed examining the crystallization of zeolites L, ZK-5 and Beta at temperatures between 175° and 105° C. Zeolite ZK-5 is being tested for hydrogen storage capability, while Beta has promising petrochemical reaction and separation applications. In addition to prior experimental operating procedures, the first demonstrations of remote ground-based commanding of these experiments in the ISS laboratory environment including parameter modification, automatic mixing, and unattended shut down were carried out during this mission.

On mission UF-2 (STS-111), CAMMP investigated new materials in another 19 separate experiments including both the microporous titanosilicate zeolite, ETS-4, which was crystallized at two different temperature levels from two different reactant mixtures, and a mesoporous silicate, MCM-41. The experiments with ETS-4 titanosilicate materials were performed to better understand their nucleation and growth mechanisms and to look at insitu production of quantum wires, while the MCM-41 experiments represent the first microgravity preparation of mesoporous materials. The improved characteristics of the IZECS control system allowed complete mixing of the reactant solutions and real time monitoring of the experiment from ground-based laboratories.

Supporting NASA's Mission

Ways in which CAMMP supports NASA's mission include, but are not limited to, the following:

To Understand and Protect Our Home Planet

Research with zeolites has the potential to reduce dependence on foreign oil and reduce pollution associated with producing gasoline and other petroleum products.

Zeolites can be used as a safer, more effective hydrogen storage devices for potential use in hydrogen-powered vehicles.

To Explore the Universe and Search for Life

Development of polymer/zeolite fuel cell for advanced space power systems

Combustion synthesis of thermal materials for advanced spacecraft design

Inorganic membranes for atmosphere gas separation on Mars

Development of Bio Sensors to control hydrocarbons, ethylene, etc with applications to closed environmental systems

To Inspire the Next Generation of Explorers

Employ graduate students in research and hardware development

Stimulating Teachers in Academic Research through Space (STARS) was established to involve elementary and high school teachers in the excitement of "real world" research and to bring that excitement to their classrooms. Eight teachers (six from inner city schools of Boston, one from a Philadelphia inner city school, and one from New Hampshire) participated in research at CAMMP over the course of a summer. They were paired into groups of two (one high school and one elementary/middle school), trained on all of CAMMP's analytical equipment, and integrated into the zeolite stability studies as well as a number of crystallization investigations. At the conclusion of the research, each team presented the science or engineering principle they had learned. In addition, their names were included on an article that came out of their work that year. The program was support 50% by CAMMP and was done at CAMMP laboratories.

Center for Biophysical Sciences and Engineering

The Center for Biophysical Sciences and Engineering's (CBSE) mission is to foster collaborative interactions between faculty and students, explore structure/function relationships of biological macromolecules, use structure-based drug design methodology to develop new pharmaceuticals for chronic and infectious diseases, and provide an opportunity for students to work with industry in space programs. These technologies have led to 4 spin-off companies, one of which is publicly traded (current value of ~$16M). The objectives of CBSE as a NASA Research Partnership Center are to promote and foster the participation and investment of the U.S. industry in the commercial development of space. Specifically for CBSE, this means forming partnerships with industrial groups and other government agencies that are pursuing commercial applications of macromolecular crystallography and structure-based drug design (a drug discovery methodology). Protein structural information is used for the discovery and synthesis of complimentary compounds that augment or inhibit the protein's biological activity for drug discovery applications. The broadening commercial application of genomic-related technologies has led to new business opportunities for the Center in this arena. Consequently, the Center also has commercialized its capabilities in gene cloning, protein expression, and protein characterization through new services it provides. Finally, CBSE has been partially supported by the Department of Defense and subsequently the Pacific Disaster Agency for the development of biowarfare therapeutics and detection systems. The detection systems have and are expected to further expand the range of CBSE biotechnologies and its affiliation with related companies.

Summary of Current Commercial Space Research

CBSE's commercial space research program provided valuable results this year from the structure-based drug design experiment utilizing the High Density Protein Crystal Growth Hardware that flew onboard the International Space Station (ISS) Stage 8A. Data collection is ongoing at CBSE and other laboratories. Preliminary analysis has indicated that at least 65% of the macromolecules flowing in the experiment produced diffraction-sized crystals. X-ray diffraction studies of these crystals will be conducted and the data will be used to determine and refine the three-dimensional structures of these macromolecules.

Supporting NASA's Mission

Ways in which CBSE supports NASA's mission include, but are not limited to, the following:

To Understand and Protect Our Home Planet/To Explore the Universe and Search for Life

Development of preventive and therapeutic pharmaceuticals for prevention of bone loss, infectious diseases, and biowarfare pathogens. Understanding the molecular function and modulation of the immune system, protein folding and cellular function.

Biosensors – Detection of pathogens: fungal, bacterial and viral contaminants in air, food, and water.

Medical diagnostics – Humphry Analyser for very early detection of macular degeneration.

Cell and Tissue research – development of a novel human tissue culture media that supports growth of human tissue in NASA's bioreactor.

Development of novel robotic equipment that is capable of freezing tissue, cells and crystals, dispensing nanodroplets in a high-throughput mode, manipulating micron-millimeter sized objects/specimens.

Development of high-throughput systems for rapidly determining protein function, protein-protein associations, protein-cell interactions, small molecule-protein interactions.

Development of "Smart Systems" using neural net technology

To Inspire the Next Generation of Explorers

K-12 structure biology workshops

Summer internships for high school and undergraduates including NSF sponsored minority program

Science competitions (winner goes to Space Camp)

The Leo Program for grade school students

International on-site lectures to 25 schools and colleges

Center for Commercial Applications of Combustion in Space

The Center for Commercial Applications of Combustion in Space (CCACS) is a NASA Research Partnership Center located at the Colorado School of Mines (CSM), specializing in combustion-related research. CCACS works with its industrial affiliates to develop and commercialize applications of fundamental and applied research conducted in its terrestrial laboratories, which are spread over five departments at CSM, and aboard NASA's microgravity platforms, including the KC-135, the Space Shuttle and the International Space Station (ISS). The ultimate goal of the research is to bring the benefits of space down to earth through the design of new and improved combustion-related processes. These processes range from the simple burning of liquid and gaseous fuels to the synthesis of exotic new materials.

FY02 was a challenging year for CCACS and the nation's research enterprise in general. Following September 11, which forced cancellation of the 2001 CCACS Annual Meeting, the economic downturn caused layoffs in industry and shortfalls in government revenues at the state level, which have had a dampening effect on research among our industrial partners and funding of projects within the center. In spite of the almost universal economic problems, the center met all of its FY02 milestones, the projects all moved forward, the new CSM research building that will house CCACS continued to take shape, and the flight hardware progressed on schedule toward Shuttle and ISS flights in late 2003 and early 2004. Less than a month after September 11, the center held a very successful workshop on water mist fire suppression, co-sponsored by the U.S. Navy Office of Safety and Survivability and the International Water Mist Association, and that drew more than 60 participants.

The CCACS affiliates group remained strong in the face of the economic downturn. The group grew through a new cooperative agreement with the Naval Research Laboratory (NRL), a new partnership with Los Gatos Research, and the acquisition by larger companies of two of our major industrial partners on the water mist fire suppression project. The NRL agreement calls for the sharing of research results and facilities, co-sponsorship of symposia and workshops, and the pursuit of joint research projects. Water mist fire suppression is the main area to which the agreement applies, but NRL is interested in other CCACS projects as well.

Summary of Accomplishments

The overall goal of the MIST project is to provide the necessary fundamental data to design the next generation of cost-effective, environmentally friendly fire suppressants. Water Mist measures the extinguishing capability of water mist on a premixed flame propagating inside a tube to gain a better understanding of water mist fire suppression phenomenon. What is learned will help CCACS design and build more effective mist fire-suppression systems for use on Earth, as well as in space. The research from MIST will ultimately lead to the manufacturing of new water mist delivery systems (nozzle, pumps manifolds), which are more effective to suppress enclosed fires. These systems may then be used to replace current fire-extinguishing system on airplanes, spacecraft, ship museums, libraries, computer rooms, and commercial cooking areas.

CCACS will use Space-DRUMS® (Dynamically Responding Ultrasonic Matrix System) to produce glass ceramics and porous ceramics on the International Space Station. This is the first time these materials will be produced inside the Station's sophisticated laboratory and the first flight of a containerless processing experiment on ISS. In the microgravity or low-gravity environment inside the orbiting Space Station, scientists can combust and solidify samples that float inside the Space-DRUMS® processing chamber. Using containerless processing, scientists can study and develop new materials in their purest form. The experiment was developed by Guigné International in Newfoundland, Canada, CCACS industrial partner for the experiment, and will be used by companies that want to process samples in space.

The Center has moved into its new headquarters on the Colorado School of Mines (CSM) Campus. The new General Research Building (GRL), which is designed to house large centers such as CCACS, was built entirely with CSM funds. The CCACS payload development, flight operations, and central offices are all located in the new building, which essentially triples the CCACS headquarters spaces. All research related to flight hardware development will be conducted in the new laboratory facilities. The CCACS Payload Operations Center (POC), which now has Internet-2 connectivity to Marshall Space Flight Center, is also in the headquarters area. CCACS ground-based research is carried out in laboratories located in five different departments around the campus.

SUPPORTING NASA'S MISSION

Ways in which CCACS supports NASA's mission include, but are not limited to, the following:

TO UNDERSTAND AND PROTECT OUR HOME PLANET

Potential applications in providing bone and dental implants, cutting tools, abrasive powders, coatings, polishing compounds, resistive heating elements, optical fibers, and insulation

Combustion research for system safety in terrestrial applications/closed systems (fire suppression systems)

TO EXPLORE THE UNIVERSE AND SEARCH FOR LIFE

Potential applications in providing drilling tools required for asteroid mining and planetary geological exploration, glass ceramics can provide high-performance thermal insulation suitable for Shuttle tiles

Combustion research for spacecraft system safety (fire suppression systems)

TO INSPIRE THE NEXT GENERATION OF EXPLORERS

Employ graduate students in research and hardware development

"Our involvement in CCACS is important to us because it enables us to explore new options and new avenues of research both with the center at the Colorado School of Mines and with the other members of the consortium. And these new avenues and new applications give rise to new products which can be of benefit not only to the company, but more importantly, to the rest of the community and the commercial world at large." Dr. John Stevens, President, ITN Energy Systems

Center for Satellite and Hybrid Communication Networks

Since its creation in 1991, the Center for Satellite and Hybrid Communication Networks (CSHCN) has been focusing its research and development, educational and commercialization efforts on hybrid communication networks. The CSHCN vision has been that the global information infrastructure on earth and in space will consist of interoperable heterogeneous networks including RF wireless, mobile wireless, satellite, optical wireless networks, wireline (cable and optical) networks. The design and implementation of such hybrid networks is of critical significance to industry (huge commercial markets), to society (affordable broadband access and information services to all sectors), to NASA (mission communications, sensor networks, aeronautical navigation, telemedicine, satellite constellations), to DoD (secure and reliable communications, information dissemination, sensor networks). Technological and commercial developments over the last decade have validated CSHCN's vision and projections; most notably the success of Direct Broadcast Systems (DBS) (satellites), and the on-going development of next generation High Data Rate (HDR) Ka band commercial and military satellite constellations, broadband wireless networks. The mission of CSHCN is to lead the research and development, demonstration, education, and commercialization of hybrid network technologies and promote an efficient and economic global information infrastructure.

Summary of Accomplishments

- Developed, implemented, and demonstrated new efficient schemes for broadcast information delivery of broadband data to vast number of users from space.
- Developed modeling and analysis tools for NASA satellite constellation missions.
- Developed modeling and performance evaluation methods and tools to design and support aeronautical communications using satellites.
- Developed, implemented and tested new Layered IPSEC (L-IPSEC) scheme that provides security for Internet communications over hybrid networks including satellites without compromising fundamental Internet compatibility.
- Developed, implemented and tested satellite-friendly Internet applications including HTTP enhancements.
- Developed new algorithms, implemented and demonstrated network security systems for broadband wireless, mobile wireless and satellite networks, including key generation, key management, authentication and trust establishment and maintenance.
- Developed, implemented and demonstrated new phase-front compensation and adaptive optics techniques for high quality direct laser-based optical communications on earth and from/to satellites and spacecraft.
- Established and leading a working group working with the Telecommunications Industry Association, the Internet Engineering Task Force and the European Telecommunication Standards Institute to standardize security, reliable multicast and Internet over satellite quality of service metrology protocols.

SUPPORTING NASA'S MISSION

Ways in which CSHCN supports NASA's mission include, but are not limited to, the following:

TO UNDERSTAND AND PROTECT OUR HOME PLANET/TO EXPLORE THE UNIVERSE AND SEARCH FOR LIFE

Improved communication, sensing, information gathering and dissemination technologies through the development of multipoint communications among sensors, robots, and spacecraft employing hybrid network technologies that link space, satellite and wireless (RF and optical) in an Internet-like fashion, including advanced security and self repairing architecture

TO INSPIRE THE NEXT GENERATION OF EXPLORERS

Attract high school, undergraduate, and graduate students in research and development of satellite and wireless communication systems and hardware and in careers in industry, academia and government

"The research work of and collaboration with the Center for Satellite and Hybrid Communication Networks (CSHCN) were strategically important and instrumental in our efforts for validating the business model and for establishing Hughes Network Systems as the premier provider of Internet via satellite services. DirecPC, which was the commercial product resulting, in part, from this collaboration, currently forms the basis of the multiple broadband platforms that Hughes Network Systems (HNS) envisages fulfilling the needs of both enterprises and consumers alike as the demand for high-speed delivery becomes even greater. Dramatic growth is envisaged for DirecPC as HNS anticipates more than 1 million subscribers by 2003. HNS has entered into an agreement with AOL that will allow AOL subscribers the ability to receive broadband multimedia content through a small rooftop dish if they use DirecPC as the delivery mechanism. The new service is to be called AOL-Plus. Our productive collaboration with the CSHCN continues vigorously through our current joint work on two-way Internet over satellite and further extensions into the new generation of Ka-band broadband satellites that Hughes is to be launching within the next three years." John Kenyon, Senior Vice President, Hughes Network Systems

Center for Space Power

The Center for Space Power (CSP) is a NASA Research Partnership Center (RPC) established at Texas A&M University in 1988. Funded by NASA, the state of Texas, non-NASA federal agencies, and industry, CSP's mission is to develop technologies for space power-related commercial ventures and for NASA mission needs. CSP accomplishes this two-pronged mission by forming partnerships among these funding groups and integrating into the partnerships the unique technical expertise available from this major research university system. As a result, CSP has been able to leverage its NASA funding by forming strong and continuing working-level relationships with most major aerospace companies and numerous smaller firms, and field a number of useful space power technologies and products.

In addition to individual, internationally recognized researchers and their teams, CSP readily enlists a host of independent Texas Engineering Experiment Station (TEES) centers specializing in technologies of direct interest to current space power issues (e.g., the Center for Nanostructure Materials and Quantum Device Fabrication (NanoFAB Center); the Center for Electrochemical Systems and Hydrogen Research; the Solid State Electronics Institute; the Interphase Transport Laboratory; and the Center for Electronic Materials, Devices and Systems). Texas A&M University also has several specialized research facilities which provide analytical and other capabilities for research projects. Having these facilities on campus and available to the researchers is not only convenient, but provides the opportunity for interaction with experts to assist in the interpretation of test results. Among these facilities are the Electron Microscopy Center, the Center for Chemical Characterization and Analysis, and the Nuclear Science Center.

Summary of Accomplishments

Designs for a fault tolerant magnetic bearing have been produced. A 6-pole redundant combination bearing with permanent magnetic bias has been designed. The design is compatible with the new NASA Glenn Research Center flywheel module. Texas A&M University will fabricate and test the bearing. Production of a prototype is proceeding. It is projected to be more capable and less expensive than current commercial bearings.

On the MultiQuantum Well Photovoltaics effort, the TEES Nanofab Center successfully grew BeTeSe barriers on Si, then grew an Si absorber layer, then another BeTeSe barrier layer, followed by a second Si absorber layer, and finally a third BeTeSe barrier, all in a monolithic stack. This growth is the key demonstration that a multiquantum well device using Si and BeTeSe is possible. The Nanofab Center also measured different bandgaps for different well geometries, demonstrating the capability to control the bandgap by controlling the barrier/well/barrier geometry.

CSP's thermal modeling and material testing enabled Advanced Modular Power Systems (AMPS) to successfully complete the first test of a 180 watt AMTEC converter for a commercial customer. CSP's modeling work showed AMPS a way to build and operate the converter so it could provide the rapid turn-on time the customer required. CSP's material testing helped AMPS pick low cost components so that the converter beat the customer's cost goal.

Fundamental advances have been achieved in materials for lithium-ion batteries. Lithium-ion batteries are currently widely used in consumer electronics. Use of these advanced materials would give batteries greater energy storage density (the same size battery would last longer or a smaller battery could have as much capacity). In addition, the materials have superior wide range temperature capability, which make them appealing for space science and exploration missions to remote and hostile environments such as Mars.

Supporting NASA's Mission

Ways in which CSP supports NASA's mission include, but are not limited to, the following:

To Understand and Protect Our Home Planet

Development of power and propulsion systems for terrestrial use including lithium batteries and solar cell development

To Explore the Universe and Search for Life

Development of power and propulsion systems for spacecraft use including lithium batteries and solar cell development

Development of vortex phase separation for propellant transfer

Magnetic bearing technology for advanced high speed gyros and flywheels to store energy or provide navigational control

To Inspire the Next Generation of Explorers

The CSP annually supports the NASA Reduced Gravity Student Flight Opportunities Program. The Center helps sponsor teams to fly experiments in the KC-135 parabolic aircraft. These students speak at high school and middle school science fairs in order to get the high school students interested in science, engineering, space and college. As a part of the presentation they show video footage of the KC-135 flight and NASA activities. Hundreds of students are contacted during these presentations.

The Center for Space Power participates in several Texas High School and Middle School Career Fairs annually reaching hundreds of students.

CSP also participates via our researchers in the Science, Technology and Youth Symposium that is sponsored by the Texas A&M College of Engineering and Texas Engineering Experiment Station, reaching the hundreds of students who come to A&M from statewide for this symposium.

"For our NASA contract to investigate two-phase flow behavior in microgravity, the CSP provided a two-phase flow facility and technical support for research flights aboard the NASA KC-135 aircraft. The CSP team configured the hardware in the test section to meet our specifications, provided a robust test facility with high-speed data acquisition, worked with the NASA JSC Reduced Gravity Office to schedule the flights, completed the safety review requirements, delivered the hardware to the test site, and provided key personnel aboard the aircraft. The reliability of the facility and the expertise of the operators resulted in two flight campaigns that were both highly successful. Obtaining microgravity data at over 100 test conditions during two flight campaigns of 160 parabolas each exceeded our expectations." Chris Crowley, Principal Engineer, Creare, Inc.

Center for Space Power and Advanced Electronics

The Center for Space Power and Advanced Electronics (CSPAE) creates products and technologies for NASA and other aerospace-related activities in collaboration with industry partners and NASA centers. Areas include solar arrays, long-life electronics, radiation-tolerant, high temperature electronic devices, fuel cell and energy storage technologies, long duration robotic power systems and advanced electric propulsion technologies for deep space missions.

It is the mission of the center to develop Hyper Electric Vehicles. The power systems for these vehicles would reach unattained levels of affordability, reliability, modularity, efficiency and performance. A wide range of vehicle classes is envisioned from spacecraft to launch vehicles to remote roving vehicles and so forth. The goal is to develop and ensure reliable, lightweight, long-life power, electric propulsion and electronics products that serve NASA and commercial mission needs.

Summary of Accomplishments

Radiation damage studies on SiC devices (junction barrier schottky (JBS), surface barrier detector (SBD), and pn-junction types) have confirmed exceptional radiation tolerance to gamma doses of 32 mRad. Irradiation of these devices with 63MeV protons is planned in early CY03. The major advance in NO passivation if SiC material (patent applied for in March 2001) has evoked strong interest by Cree, Inc. who is being courted as an industry partner for the center. This proprietary coating has reduced interface state density over an order of magnitude beyond best available industry practice.

Demonstrated significant improvement in mechanical shock and thermal shock reliability of area array, chip scale packages by using underfill. Because of their small volume and weight, chip scale packages (CSPs) are becoming the package of choice for many electronic devices. However, the reliability of these packages is not as good as traditional quad flat packages, particularly in mechanical shock. The use of underfills to mechanically couple the CSP to the printed circuit board dramatically improved reliability (5-6x). Manufacturing process using capillary flow and fluxing underfills were developed, along with a network process.

CSPAE has been successfully applying digital control technology for power supplies and capitalizing on their inherent advantages of health monitoring, communication, and self diagnostics over the past 3 years. Because of their many advantages, digital control of all electronic power supplies will take over from analog controllers in the next few years. The Center's goal in this work is to achieve fast transient response as well as accurate steady-state response. We have demonstrated feasibility using a low-cost, 8-bit microcontroller with both a PID controller and a fuzzy logic controller. The approach used a voltage mode control of buck and boost converter operating in both discontinuous and continuous modes using 8-bit microcontrollers.

Pulse testing of RuO2 supercapacitors confirmed their ability to operate at 10 kHz repetition rates. This is suitable for inclusion in a hybrid power system for a radar system. In order to understand the long-term changes in the RuO2 devices, continuous impedance spectroscopy scans were made every 30 minutes for times up to one week. These test results confirmed that control of the moisture content of the capacitor was critical to both long term stability and maximum performance. Control of both layer thickness and moisture content is critical. Proper packaging technology will be required to ensure the container holds the mosture content of the films stable of the lifetime desired.

Supporting NASA's Mission

Ways in which CSPAE supports NASA's mission include, but are not limited to, the following:

To Understand and Protect Our Home Planet

Development of power and propulsion systems for terrestrial use including low temperature lithium batteries and solar cell development for commercial satellites

Development of loop heat pipe technology that enables deployable radiators with no moveable fluid coupling for commercial communications satellites

High efficiency solar cells for terrestrial power generation and commercial satellites

To Explore the Universe and Search for Life

Development of high density electronics "Area Array" packaging

Development of super capacitors for energy storage

Development of high speed flywheel technology for energy storage or navigational control

Development of power and propulsion systems for spacecraft use including low temperature lithium batteries and solar cell development for NASA spacecraft

Development of loop heat pipe technology that enables deployable radiators with no moveable fluid coupling for NASA spacecraft

High efficiency solar cells for NASA spacecraft

To Inspire the Next Generation of Explorers

Employ graduate students in research and hardware development

Creating leaders and explorers of tomorrow by providing enthusiastic and competent new hires for industry and government - Research Partnership Centers (RPCs) are effective at inserting students into industry partners. Students worked for them in developing products, they know how aerospace works, and they have worked to milestones and deliverables. The RPCs are helping to eliminate the shortage of scientists and engineers in an exceptionally effective manner in addition to helping in the development of the products of the future and thus are supporting economic superiority.

Auburn University hosts "E Day" (Engineering Day) each year for high school students. The project leaders associated with CSPAE are actively involved in this program. There have been several oral presentations at local schools speaking to students to incite and inspire interest in various fields of education with much emphasis being put on space, terrestrial programs, and activities as they relate to the goals of the CSPAE.

Commercial Space Center for Engineering

The Commercial Space Center for Engineering (CSCE) promotes commercially funded engineering research and technology development (ERTD) using the International Space Station (ISS) or other orbiting platforms as a test bed for developing and validating advanced spacecraft technology. The Center also employs its engineering research capabilities to develop and market new spacecraft technologies, such as advanced attitude sensors or relative navigation sensors. In this role, the CSCE conducts the engineering development required to raise the technology readiness level of a novel concept (e.g., an advanced star tracker) to a point where an industry partner will license the technology. CSCE then works with the industry partner to complete development and commercialization of the new product. Companies partnered with CSCE leverage our engineering expertise and facilities to develop prototypes of new space hardware products and payloads for on-orbit engineering experiments and demonstrations. Much of the commercial flight hardware developed in this fashion also directly supports NASA mission needs.

NASA established the Commercial Space Center for Engineering at Texas A&M University in 1998. A key objective of the cooperative agreement between the Marshall Space Flight Center/Space Product Development (MSFC/SPD) and CSCE is to generate industry-funded ERTD payloads for the ISS. Focusing the unique capabilities of the ISS on this market in a timely fashion can provide an early demonstration of ISS commercialization and significantly improve station utilization without increasing demand on severely limited crew resources.

Summary of Current Commercial Space Research

COMIMG/BAE (Commercial Imager/Broadband Antenna Experiment). This Express Pallet payload consists of an advanced hyperspectral imager and phased array antenna communication system. In FY02 the Center completed the Concept Definition Study (CDS) for this project. The final CDS, a 140-slide proprietary briefing, resolved all key feasibility issues and provided details on the market and business case for the flight experiment. The CDS included PDR-level descriptions of the mission, imager and comm concepts, mechanical design, and structural, thermal, orbital and pointing analyses.

During FY02, CSCE completed fabrication, assembly, and flight qualification of the StarNav I hardware, delivered it to KSC, and conducted integrated verification testing with the Spacehab module to establish readiness for the planned launch of STS-107. StarNav I is a prototype of an advanced star tracker.

StarNav II is an advanced version of the StarNav I technology. It is scheduled to fly as a New Millenium Project demonstration as part of NASA's Geostationary Imaging Fourier Transform Spectrometer (GIFTS). This technology underlies the commercial star tracker product that will be manufactured and marketed by CSCE's industry partner. In FY02, the CSCE StarNav team accomplished significant design upgrades while developing the StarNav II engineering model. These design improvements were accepted by the NASA GIFTS system contractor and formed the basis of a major increase in system life expectancy (later formalized in early FY03). Also in FY02, the CSCE team completed detailed design of a prototype in preparation for component validation in the laboratory and under relevant environmental conditions.

CSCE initiated operation of the Space Engineering Institute (SEI). The Institute's mission is to expand the pool of future U.S. aerospace technology workers and simultaneously foster the development of innovative space technologies for the nation. The Institute uses CSCE's facilities and professional staff and collaborates with faculty from the TAMU College of Engineering to implement its programs.

CSCE opened the Space Systems Integration Laboratory, providing over 10,000 SF of floor space and equipment for the fabrication, assembly, and test of space hardware.

Supporting NASA's Mission

With its focus on industry-funded development of advanced technology for spacecraft, CSCE activities frequently support NASA missions in a variety of ways. Some examples of CSCE support for NASA are listed below under the three key statements defining NASA's mission:

To Understand and Protect Our Home Planet

CSCE and its industry partners designed an advanced hyperspectral imaging system with high-speed data download capacity and an ISS-based experiment to validate operation from low earth orbit. In addition to its commercial applications, this 256-channel, high resolution system also satisfies NASA's requirements for Earth observation missions and environmental monitoring. The 600 megabit-per-second technology will be available to meet NASA's download requirements for future earth observation missions.

To Explore the Universe and Search for Life

CSCE and its industry partners are developing and demonstrating a number of commercial satellite technology advances that also solve engineering problems for NASA spacecraft exploring the universe. Some examples are described below:

Development and space test of an elastic memory composite (EMC) hinge for deployment of solar panels and other satellite components. High-damping, low activation energy allows simple, light weight component designs yielding significant mass savings with no scaling limitations for commercial and NASA spacecraft.

Development and space test of an advanced star tracker. Unique dual field-of-view, fully autonomous, low mass star tracker with on-orbit calibration and patented lost-in-space algorithm provides highly accurate spacecraft pointing knowledge. NASA plans to use this product on its GIFTS New Millenium spacecraft mission.

Development and space test of VisNav, a smart sensor/beacon technology for autonomous rendezvous and docking in space. Enables free flyers for research and re-supply missions to safely and autonomously dock with ISS and other vehicles. Enables unmanned NASA satellite servicing and refueling missions

To Inspire the Next Generation of Explorers

CSCE is working with another Commercial Space Center at Florida Atlantic University to develop and flight qualify a high-definition video camera for use on ISS. This technology will be used by NASA for educational purposes and to create inspirational content for motivating future space scientists and engineers.

CSCE established the Space Engineering Institute to provide practical training and hands-on experience that strongly encourage students to pursue engineering degrees leading to careers in space systems development and operations. These graduates will be uniquely qualified in space systems engineering and instrumental in alleviating the national shortage of intellectual capital now threatening the U.S. aerospace economy.

Consortium for Materials Development in Space

The Consortium for Materials Development in Space (CMDS), located at the University of Alabama in Huntsville (UAH), supports applied research and product development activities in electro-optical and photonic materials, biotechnology, and the life sciences. Its commercial efforts are industry-driven and product-focused, and are oriented towards the use of the microgravity environment as an adjunct to ground-based research and development. In order to meet industry wants and needs, CMDS has expanded its overall scientific capabilities through the formation of strategic alliances with research centers at UAH, with the Bone Cell Core Facility at the University of Alabama at Birmingham (UAB), and with the Optical Sciences Center at the University of Arizona (UA). These partnerships have led to the successful recruitment of new industry affiliates and progress in the development of a broad range of products. Current research ranges from new materials for organic transistors to proteins affecting bone cell growth, new drug targets for osteoporosis and breast cancer treatment, novel technology for rapid identification of infectious agents in complex mixtures. CMDS also continues to educate and support students in the areas of materials science, biotechnology and life science research, and space flight hardware development.

Summary of Accomplishments

Significant milestones were achieved on all CMDS projects co-funded by industry. Scientists in the Laboratory for Structural Biology (LSB) at UAH, in collaboration with Nektar Therapeutics (formerly Shearwater Polymers, a CMDS spin-off company), continued their efforts to identify and produce candidate therapeutic proteins for use with their patented polyethylene glycol drug delivery technology. Nektar has also filed a patent application on a bone-specific drug delivery vehicle, and Phase I clinical trials will be initiated in the near future.

CMDS developed a research collaboration with a new commercial partner, Prototek, Inc. of Dublin, California. Prototek is an emerging biotechnology company focused on the deployment of proprietary inhibitor compounds for treatment of AIDS, dementia, myasthenia gravis, Alzheimer's disease, Huntington's disease, and other neurodegenerative disorders. The scientific partnership between CMDS, the LSB at UAH, and Prototek investigates the interaction between Prototek's proprietary compounds and active sites on proteins associated with disease progression. The ultimate goal of the collaboration is to provide detailed structural information that will enable the development of more effective and highly specific inhibitor compounds.

CMDS's leading commercial materials projects deal with the development of new methods for preparing single crystal organic field effect transistors, or OFETs, for use as switches in flat panel displays. Potential products incorporating OFETs include pagers, digital phones, personal digital assistants and other hand-held electronic devices, automotive dashboard displays, and watches. This applied research project is a collaboration between CMDS, the Optical Sciences Center at the University of Arizona, and Durel Corporation, Chandler, Arizona. While steady progress was made in FY2002 numerous challenges remain before these emerging technologies can realize their potential in the flat panel display market. CMDS will conduct experiments in the enabling environment of microgravity. The first flight experiment is now planned for November 2003 on the International Space Station (ISS).

In addition to its commercial space product development efforts, CMDS is building hardware for the ISS. The Space Product Development Experiment Module, or SPDEM, will be employed for growing inorganic crystals for acousto-optically tuned devices and for processing ZBLAN, a heavy metal fluoride glass for improved optical fibers. CMDS's physical vapor transport hardware, originally designed for deposition of non-linear optical materials, is being redesigned to ISS and industry specifications as the DOME (Development of Organic Materials for Electronics) spaceflight hardware. It will be employed on ISS for preparation of thin films for OFET applications. A low temperature, low energy carrier (LoTEC") for transport of biological specimens to and from ISS has been designed, constructed and tested.

Supporting NASA's Mission

Ways in which CMDS supports NASA's mission include, but are not limited to, the following:

To Understand and Protect Our Home Planet

Deployment of a novel platform technology for rapid identification of infectious agents in blood, serum and other complex mixtures

Development of DNA microarrays for fundamental genomics research

Structurally characterize proteins associated with the process of bone growth, resorption and repair as a means of designing more effective therapies for treatment of osteoporosis and other diseases of bone and cartilage biominralization

Development of new and improved organic materials for flexible flat panel displays such as electronic smart cards and personal data assistants (PDAs)

To Explore the Universe and Search for Life

Development of universal detector technology for identification of RNA and DNA in newly discovered microorganisms

Development of strategies to compare protein structure and function in ancient versus contemporary organisms in order to determine the limits of life on Earth and whether these limits may apply elsewhere in the universe where there is carbon-based life

Development of new materials for fabrication of acousto-optically tuned filter devices and optical fibers that may prove useful in near-IR transmission devices

Structurally characterize proteins associated with the process of bone growth, resorption and repair to design intervention strategies to prevent the development of disuse osteoporosis in astronauts during long-duration spaceflight

To Inspire the Next Generation of Explorers

A number of protein crystallization workshops were conducted for more than 250 K-12 students and educators

CMDS, through the Laboratory for Structural Biology at UAH, taught a three-day directed study on structural biology at National Youth Science Camp. The delegates were chosen for this camp represent the two most outstanding senior science students from each state. The directed study provided an introduction to the methods used in determining protein and nucleic acid structure, combined with a hands-on lab to teach the principles of protein purification and crystallization.

"We are very pleased at Durel to be the industry affiliate for the DOME (Development of Organic Materials for Electronics) project in collaboration with the CMDS and the Optical Sciences Center at the University of Arizona. Development of large area, low cost organic electronics is a challenging and exciting area of applied research and is likely to generate both new technologies and novel products. The use of the enabling environment of microgravity to gain a better understanding of the factors associated with successful thin film deposition will be instrumental in developing these new products." William Coghlan, Principle Research Engineer, Durel Corporation

Imaging Technology Commercial Space Center

The Imaging Technology Commercial Space Center (ITCSC) - formerly the Space Communications Technology Center - is a non-profit consortium of industry, academia and government to conduct space-based technology research and development in electronic imaging and communications. Its mission is to develop the commercial use of digital imaging for telemedicine, surveillance, safety and high definition images for the media.

Summary of Current Commercial Space Research

In 2002, the center developed a telemedicine system that includes a wireless high resolution high definition ultrasound scanner that is suitable for use in space. The wireless ultrasound unit, combined with a QUAD HD 3-D CMOS camera could be incorporated into a telehealth system for use on ISS, on extended space flight and terrestrially for unlimited telemedicine and safety applications. Currently, commercial HDTV cameras do not survive the radiation levels encountered in space. The system under development at ITC would be space qualified. Such a system not only provides diagnostic facilities in space - it also advances the capability of terrestrial telemedicine applications.

The products developed by the ITCSC are commercially oriented. The center has developed the highest resolution cameras and ultrasound scanners in the world for use in telemedicine systems. Imaging from the ITCSC-developed QUAD HD Camera and PC-based Ultrasound unit can be sent via satellite or optical fiber to interactive displays. Corporate partner, BellSouth, donated a 1.5-gigabit fiber link between two center laboratories in Boca Raton and Fort Lauderdale (30 miles apart). The link carries digital video bit streams of 1.5 gigabits – equal to 1000 T1 lines) and is used to demonstrate the viability of high definition imaging used for remote medical diagnoses.

Remote diagnosis using video imaging has received considerable attention in recent years. Over 80 percent of all medical problems can be adequately diagnosed remotely using video and other electronic sensors, such as ultrasound, according to clinical studies. The 2003 ultra high resolution QUAD HD camera has 50 times the number of resolvable pixels as cameras previously used in telemedicine. The CMOS sensor incorporated into the camera system will significantly reduce size, power and cost. The camera mockup shown here is the approximate size of the next generation 2003 QUAD HD 3-D CMOS color camera. Important to NASA is the fact that current commercial HDTV cameras do not survive radiation levels in space.

The ITCSC 2003 program includes designing and fabricating a QUAD HD 3-D CMOS camera for use in space and at high altitudes. These cameras are also needed for surveillance, safety and for providing HDTV images for the media.

This camera could also be included in a telemedicine system. This system or system components (wireless high resolution ultrasound, QUAD HD 3-D CMOS camera) could be used to enable the following NASA and commercial applications:

Commercial telemedicine services including medical diagnosis, medical education, medical consultation, telemedicine systems, etc.

Light-weight, inexpensive, compact unit for use in NASA missions; feasible way to provide healthcare to remote terrestrial areas and in space.

Light-weight, inexpensive, compact unit for medical applications in the doctor's office

Remote video surveillance

Structural engineering, manufacturing and maintenance arenas (ultrasound is useful in remotely analyzing "hidden" stress fractures or other structural anomalies in hazardous areas or areas that are difficult to analyze traditionally, such as oil tankers, bridges, airplanes, rockets, ships, etc.)

Medical video conferencing

Observations for mission safety

Scientific experiment monitoring

Electronic origination of motion pictures

SUPPORTING NASA'S MISSION

Ways in which ITCSC supports NASA's mission include, but are not limited to, the following:

TO UNDERSTAND AND PROTECT OUR HOME PLANET

Development of techniques for transmitting video, audio, and data by satellite

Development of ultra high resolution imaging technologies for geographic, atmospheric and surveillance informatics, telemedicine

TO EXPLORE THE UNIVERSE AND SEARCH FOR LIFE

Development of a Ultra High Definition 3-D TV camera with resolution 4 times that of current commercial units and improved radiation hardening for high altitude and space use

TO INSPIRE THE NEXT GENERATION OF EXPLORERS

Employ and train graduate students in research and hardware development

Development of Ultra High Definition 3-D TV system to generate video of International Space Station (ISS) crew activities for distribution to the Discovery Channel or other media

Medical Informatics and Technology Applications Consortium

The Medical Informatics and Technology Applications Consortium (MITAC) is a center of excellence that specializes in the areas of telemedicine, telehealth, and medical informatics. MITAC, located on the campus of Virginia Commonwealth University in Richmond, VA works closely with NASA to meet NASA's needs in the area of telemedicine, telehealth, and medical informatics especially for those individuals located in extreme and remote environments. The application of telemedicine in the delivery of health care in the environs of space is of extreme importance to the astronaut and to ground controllers. These same needs and concepts are of great importance regardless of the location of the patient in need or the caregiver. MITAC's vision is to 'Explore new technologies in medical informatics and health care delivery systems that will revolutionize health care in space and on Earth. MITAC accomplishes this through establishment of partnerships with academic, industrial, and government entities dedicated to the improvement of health care through the use of space science and technology. In addition, MITAC helps maintain the United State's competitive lead in commercial applications of medical informatics and telemedicine, the development and application of innovative technologies that can be embraced by human space flight, and the integration of communications, information systems, and electromechanical interfaces between patient and health care teams.

Current efforts are providing a strong foundation for expansion of telemedicine and telehealth capabilities in many areas in the U.S. and around the world. Through unique partnerships, MITAC is recognized as a world-class telemedicine center of excellence. These partnerships lead to new approaches and unique solutions for providing health care management in remote environments. MITAC utilizes and validates a variety of technologies that focus on low bandwidth telecommunications. Such efforts are directly related to the challenges faced in providing medical support during human space flight. Through partnerships with telemedicine-oriented industries, MITAC develops new technologies and strong infrastructure that shows commercial possibilities in homeland security and international health.

MITAC's work is recognized through peer-review publication on an international scale, attendance at national and international conferences, and through interaction with a variety of organizations. MITAC partnered with TeleVital (Milpatis, CA) to develop and validate a method of monitoring patients under anesthesia in a mobile surgical facility in Ecuador using the World Wide Web and low bandwidth telecommunications to link Ecuador to MITAC in Richmond. MITAC is also in discussion with the Department of Defense (DoD) to provide expertise in developing a strategic plan for telemedicine support on an international scale. This is leading to efforts in telemedicine training in Uzbekistan with DoD's Partnerships of Peace Information Management Systems and a U.S. State Department initiative to support telemedicine efforts in Afghanistan.

Although MITAC does not have direct access to space flight, it has worked closely with NASA to meet its needs and commitments with regard to telemedicine. NASA has played a major role in telemedicine development for nearly 45 years. MITAC, through its architecture, continues that role on behalf of NASA by interacting with industry, academia and the international community.

Summary of Current Accomplishments

Although MITAC does not focus its efforts on direct space flight opportunities, it has developed and validated a number of technologies that capitalize on wireless and low bandwidth telecommunications capabilities, information management systems, and unique needs. Managing health issues at a distance are of great concern not only to NASA but the entire population of the Earth. The ability to provide access to health care information and medial expertise is paramount in addressing medical needs.

MITAC has been highly successful in develop and validating telemedicine technologies in unique test beds around the world. Its competencies and technical expertise are sought after to meet unique challenges such as working with DoD to develop strategic planning in telemedicine for the DoD as well as working with the U.S. State Department to develop possible solutions in Afghanistan.

During the past year, MITAC published over 15 manuscripts in peer-reviewed journals and have written definitive text for books in the discipline of telemedicine. MITAC is also working with several graduate students on both PhD and MS level degrees. This work permits a steady stream of intellectual property to be transferred to the University and then the commercial market place.

Supporting NASA's Mission

Ways in which MITAC supports NASA's mission include, but are not limited to, the following:

To Understand and Protect Our Home Planet

Development of unique remote diagnostic capabilities for terrestrial applications in remote regions and fast response to disaster areas

To Explore the Universe and Search for Life

Development of remote diagnostic capabilities used to monitor astronaut health status

Develop and validate systems to support remote health care and medical informatics in extending human presence is space

To Inspire the Next Generation of Explorers

MITAC has developed a comprehensive training capability to support education in telemedicine. This training ranges from the undergraduate honors students at VCU to the physician-student at NASA's East West Science Center (EWSSC) at the University of Maryland. MITAC has transferred this capability into a comprehensive curriculum for the NASA flight surgeon.

ProVision Technologies

ProVision Technologies (PVT) is focused on developing hyperspectral imaging solutions for real world problems both in space and here on Earth. This unique form of imaging splits reflected light into hundreds of discrete, contiguous bands of energy. The sensor then measures the intensity of that energy, ultimately forming an image with spatial and spectral information. This technique of imaging is being used to provide solutions to a diverse set of industries, including food inspection, forensic science, wound care, and ophthalmology. Research has focused on the visible and near-infrared portions of the spectrum, but soon will expand to cover the ultraviolet and shortwave infrared portions as well.

One of the traditional niches for hyperspectral imaging has been Earth observation. Typically, remotely sensed imagery collected from airborne and spaceborne platforms has been used to study agricultural, environmental, and military processes. In an effort to serve this established marketplace, PVT has begun the work of modifying its hyperspectral imaging system to collect imagery that will possess both high spatial and high spectral resolution from the International Space Station. The sensor will be mounted in the U.S. Laboratory's (USL) Window Observational Research Facility (WORF) where it will collect visible and near-infrared hyperspectral imagery through the Window.

Researchers at PVT are working with a host of users, including the Government, academic institutions, health care facilities, and private companies to develop application-specific solutions. As a result of these relationships, PVT has experienced a significant increase in both staff and overall funding during FY02. However, even with these increases, it was recognized that applications could not be developed fast enough to keep up with such a diversified and strong interest. Consequently, PVT made a strategic decision to start a for-profit spin-off company, Photon Industries, which will build and market turnkey hyperspectral imaging systems to the public. This approach will make it possible for researchers from many disciplines to simultaneously develop solutions to a wide array of problems using this technology.

Summary of Accomplishments

PVT continued its joint effort with IRIDEX Corp to improve infrared laser treatment for macular degeneration. Patient data was obtained at a local ophthalmology clinic to evalue hyperspectral imaging analysis as a determinant of safe and effective laser dosage. A positive outcome from this research will lead to a revolutionary change in laser surgery, wherein the interaction of the laser with tissue can be monitored during the course of surgery.

Hyperspectral analysis of reflected energy from a wound holds great promise to assess and monitor wounds. Wounds incurred by humans during space flight do not heal as rapidly as wounds on Earth. In the United States, approximately 5 million Americans suffer from chronic open sores that can become seriously infected, gangrenous, and may eventually require amputation of a limb. Many factors can influence a wound to become chronic, or slow to heal. PVT has been working with patients and doctors at Memorial Hospital in Gulfport, Mississippi, to develop the use of hyperspectral imaging technology to identify the severity of a wound and also to help monitor wound healing.

PVT has been using a visible/near-infrared hyperspectral imaging system as a new approach in studying diseased human tissues. Preliminary results have revealed changes in the tissues that are not recognized and/or appreciated by the human eye. The focus has been centered on blood perfusion and oxygen saturation in flesh wounds. Specialized software analyzes the data and draws the doctor's attention to suspicious areas that the doctor then reviews more carefully. This allows observation into local blood oxygen supplies of tissue as opposed to common point measurement techniques such as pulse oximetry and optical fiber probing. Thus far, clinical tests have shown this technology could result in earlier detection of necrotic and ischemic tissue to assist doctors in examining and treating wounds.

The ultraviolet hyperspectral imaging sensor (200 to 400 nanometers) was built this year. There is no other ultraviolet hyperspectral push broom scanning imaging sensor like this in the world. PVT is truly at the sharpest edge of cutting this new technology. Only two other companies in the world, one in Germany and one in Finland, could develop components needed to build this sensor. This system can be placed on several platforms such as tripods, copy stands, aircraft, and space platforms.

SUPPORTING NASA'S MISSION

Ways in which PVT supports NASA's mission include, but are not limited to, the following:

TO UNDERSTAND AND PROTECT OUR HOME PLANET

Application of hyperspectral imaging technology for non-invasive diagnostic evaluation ranging from early detection of skin disease to pathogens in food products, forestry management, oil and mineral detection, counterfeit document detection (in collaboration with the FBI), determining specific crop pesticide prescriptions, and even potential homeland security applications.

TO EXPLORE THE UNIVERSE AND SEARCH FOR LIFE

Hyperspectral imaging technology could be adapted for crew health monitoring (wound care, mold detection, retinal imaging, food safety, sterile H_20 supply)

TO INSPIRE THE NEXT GENERATION OF EXPLORERS

"Cosmic Classroom" provides high-resolution imagery for integration into classroom curriculum content

"The advanced imaging capabilities offered by ProVision Technologies may give doctors an unprecedented new opportunity to observe, measure and optimize the therapeutic effects of these advanced treatment techniques." Eduardo Arias, Sr. Vice President, IRIDEX Corporation.

Solidification Design Center

The mission of the Solidification Design Center (SDC) is to understand and control gravitational effects in solidification-related industrial processes for the benefit of producers and users of metal castings. SDC has just completed a fruitful and exciting year of metal casting research with the U.S. foundry industry, a $25 billion a year manufacturing sector. A number of industry-sponsored projects are underway expanding the Center's knowledgebase of critical thermophysical and metallurgical data essential for enhanced competitiveness of this vital industry. In addition, hardware design and development activities for materials research on the International Space Station (ISS) continue in anticipation of a robust utilization of the orbital facility.

SDC's aggressive research agenda is primarily focused on the following key research areas:

- Acquisition of thermophysical property data of commercial alloys;
- Measurement of metallurgical data of commercial alloys;
- Development of advanced metal castings and related manufacturing techniques for commercial applications; and
- Development of software for simulating flow of particulates and their binders.

Summary of Accomplishments

A comprehensive thermophysical properties database for commercial alloys is required for the development of reliable computational models of production casting processes. A number of commercial alloys have already been characterized and the data delivered to industry. Computational models can be critical for foundries to reduce times to market, enhance quality levels, and minimize manufacturing costs.

In addition, the next generation of manufacturing processes will require diverse metallurgical data for control of metallurgical microstructures and mechanical properties of cast components. SDC research teams are pursuing basic metallurgical data for a number of advanced alloys and processes through the American Foundry Society (AFS)/industry peer-review process. Microstructural development in a variety of ferrous alloys is being investigated by PMS Inc. of Buchanan, MI. ARENA, LLC (formerly Flow Simulation Services) of Albuquerque, New Mexico and GM (Warren, Michigan) are developing software to enhance the design of aggregate mold making processes. Auburn University (Auburn, Alabama), Ford Motor Company (Deaborn, Michigan) and Stahl Specialty Co. (Kingston, Missouri) are developing a low-cost sensor to measure dissolved hydrogen levels in molten aluminum. Convection effects during the feeding of steel castings is under study by CANMET (Ottawa, Ontario) with Maynard Steel Casting Co. of Milwaukee, Wisconsin and Frogswitch Manufacturing Co. of Carlisle, Pennsylvania.

SDC also partners with individual manufacturing companies on more near term and proprietary research and development to quickly improve productivity and competitiveness through application of advanced technologies. Auburn University and Citation Corp. (Birmingham, AL) are advancing semi-solid rheocasting of non-ferrous materials for automotive applications. Harmony Castings (Harmony, PA) is working with SDC to expand the process capability of the 'V'-process, a unique metal casting process where environmental emissions during casting are considerably reduced due to the absence of binders in the molding materials. Increased understanding of how gravity affects solidification phenomena has

lead Herman Williams Company (Birmingham, AL) to invest in centrifugal casting techniques to increase the effective 'g' during casting. A new SDC project is investigating how enhanced 'g' levels can be reliably exploited to enhance metallurgical structures of ferrous castings. Goldens Foundry (Columbus, GA) is utilizing SDC technology to automate their production line for engineered ductile iron castings. Finally, Stahlschmidt & Maiworm USA broke ground in Auburn, AL on a new $40M manufacturing plant to produce high quality cast aluminum wheels. The $40M facility will employ 300 people and several joint R&D projects are planned with the SDC.

The development of metal casting research techniques for SDC use on the ISS also made important progress during 2002. In the spirit of "Vulcan," the mythological metalworker in service to the Roman pantheon of gods, the Solidification Design Center, Wyle Laboratories (Huntsville, AL) and Anter Corp. (Pittsburgh, PA) are developing the VULCAN™ modular series of ISS flight hardware to enable a number of key research activities to acquire low-g data which serves the metal casting industry. VULCAN-TP™ (Thermophysical Properties) successfully passed the Phase II Safety Review during 2002 and is now being fabricated for delivery to the space station. Prototype designs of future VULCAN™ modules, e.g., VULCAN-DS™ (Directional Solidification), are also being developed for future space experiments.

In summary, 2002 has been a truly outstanding year for the Solidification Design Center. Industry investments continue to increase and industry-sponsored projects are establishing the knowledge base for future experiments on the ISS beginning in 2003.

SUPPORTING NASA'S MISSION

Ways in which SDC supports NASA's mission include, but are not limited to, the following:

TO UNDERSTAND AND PROTECT OUR HOME PLANET

Technology development to improve casting processes for metals and alloys for a wide range of material products; non-invasive diagnosis of faults in prototype units prior to full production

TO EXPLORE THE UNIVERSE AND SEARCH FOR LIFE

Development of technologies to improve casting processes for metals and alloys for a wide range of material products including light weight strong castings such as ware resistant aluminum alloys and centrifugal casting for rocket engine parts

TO INSPIRE THE NEXT GENERATION OF EXPLORERS

Employ graduate students in research and hardware development

Build unique partnerships among colleges and industry to develop the next generation of leaders

CEO Seigfried Teichert said that "Stahlschmidt & Maiworm USA expects to cooperate with Auburn University's Solidification Design Center to develop and operate the most advanced alloy wheel manufacturing facility in the U.S."

Texas Center for Superconductivity and Advanced Materials

The mission of the Texas Center for Superconductivity and Advanced Materials (TcSAM) is to create advanced thin film materials and devices for commercial application through vacuum growth technologies using terrestrial and space vacuum environments. The Texas Center for Super-conductivity and Advanced Materials exemplifies the concept of a business enterprise within the boundaries of a university. TcSAM's objectives are to stimulate the use of thin film technologies for product development; to utilize the ultra-vacuum of space for thin film epitaxial growth; to integrate the business, legal and technology development sectors of academia for new product development; and to produce new industry-driven electronic, optical and superconducting thin film materials and devices for both terrestrial and space use. The University of Houston has housed the Texas Center for Superconductivity and Advanced Materials since its inception as the Space Vacuum Epitaxy Center (SVEC) in FY87. The Center currently occupies over 11,000 sq. ft. of laboratory and office space including specially constructed clean rooms for thin film materials processing.

Summary of Accomplishments

Development of a new resistive random access memory technology took place this year in partnership with Sharp Laboratories of America. The Licensing Agreement with Sharp was officially executed in December 2001. Early developments have resulted in a two state device that can be switched in times shorter that ~15ns and with pulses of ~ 3.5V with a change in resistance of more than two orders of magnitude. This technology is expected to result in a multi-state memory device which is non volatile and radiation resistant.

Tunable light sources are needed for spectroscopic chemical and biological sensing, telecommunication, and many other applications. TcSAM reported the world's first grating-tuned external cavity quantum cascade laser at the Conference on Lasers and Electro-Optics (CLEO) at Baltimore on May 6-11, 2001. This year, TcSAM significantly improved the tuning range and operating temperature of these devices. With anti-reflection coating on one facet and better grating, the tuning ranges were 0.127 and 0.14 micron at –30 and –200˚C, respectively. The weak temperature dependence of the tuning range is extremely encouraging. Furthermore, with high reflection coating on the other facet, this device is expected to deliver ~ 10 mW peak power at – 30˚C, which is sufficient for many of the chemical and biological sensing applications.

In January 2002, the Space Vacuum Epitaxy Center (SVEC) Commercial Space Center (CSC) merged with the Texas Center for Superconductivity at the University of Houston (TcSUH). TcSUH was created in 1987 by the Texas State Legislature after Paul Chu discovered materials that become superconductors at a temperature above the boiling point of liquid nitrogen. These materials, called high-temperature superconductors, have shown potential for delivering electricity more efficiently and cheaply than current technologies. By combining the strengths and resources of these two centers, UH can further advance the opportunities for both basic and commercial materials research, and bring industrial involvement more prominently into the program.

The "Bionic Eye" is a ceramic oxide micro-detector array which could be implanted in the retina to restore sight to patients whose retinas have been damaged by injury or disease. In FY2002, TcSAM demonstrated biocompatibility of the implants in rabbits. Human trials are being arranged for early 2003.

TcSAM's research with several industrial partners into the possibility of robotically manufacturing of solar panels utilizing in-situ resources on the Moon continued to progress in FY2002. TcSAM was able to create several glassy substrates that could be used for solar panels by melting the JSC-1 (Johnson Space Center provided) lunar regolith simulant. Partner Penn State University began the process of depositing silicon solar cells onto these substrates.

Supporting NASA's Mission

Ways in which TcSAM supports NASA's mission include, but are not limited to, the following:

To Understand and Protect Our Home Planet

Compact and low-cost infrared lasers for environmental monitoring, biological sensors and wireless communications

One-chip microintegrated optoelectronic chemical sensors

To Explore the Universe and Search for Life

Development of emission structures and arrays developed for use as electron emitters in flight mass spectrometer units

Development of new technologies useful on advanced spacecraft:

- High efficiency and radiation hard solar cells
- Thermovoltaic converters
- Thick film superconducting wire
- Non-volitile, multi-valued computer memory
- Compact and low-cost infrared lasers for environmental monitoring, biological sensors and wireless communications
- One-chip microintegrated optoelectronic chemical sensors
- High energy density, high temperature ceramic capacitors
- Field emission pressure micro sensors to measure pressures, flows and accelerations

Development of technology for manufacture of solar cells from planetary resources

To Inspire the Next Generation of Explorers

TcSAM employs graduate students in research and hardware development.

TcSAM researchers routinely visit area schools (K-12) to speak, give demonstrations and conduct workshops related to TcSAM's space activities, and offer tours to students and teachers by request. In addition, the center also provides on-line question and discussion forums for teachers of physics and all other subjects.

TcSAM also hosts High School Summer Internships, Distinguished Lecture Series for High Schools, annual Open House, yearly Science Carnival for fifth-grade students.

TcSAM awards the Materials Science Awards in the senior division (Grades 10-12) at the Science Engineering Fair of Houston held each Spring and provides judges for this and similar events.

Wisconsin Center for Space Automation and Robotics

The Wisconsin Center for Space Automation and Robotics' (WCSAR) mission as a NASA Research Partnership Center (RPC) is to support industry in the development and commercialization of novel products and technologies derived from space-based plant biotechnology research, and thereby, to contribute to an improved quality of life on Earth and to a long-term human presence in space.

Established in 1986, WCSAR supports agribusiness research and provides industry partners with advanced environmentally-controlled technologies, large-scale environmentally-controlled plant production facilities, and robotics automation technologies.

Located at the University of Wisconsin - Madison, WCSAR is sponsored by NASA through a Cooperative Agreement mechanism and funded primarily by NASA and industry. Secondary contributions come from other state and federal government agencies as well as private foundations. WCSAR partners and collaborates with industry by jointly performing both ground-based and space-based research to gain new knowledge that can be applied to create or improve a commercially viable product or process here on Earth.

In addition to collaborating with industry and academia, WCSAR also collaborates with other RPCs and other NASA centers with goals of (a) developing technologies that will contribute to long-term human exploration of space, (b) providing key features of advanced life support systems and extraterrestrial agronomic facilities, and (c) co-sharing the technologies and hardware, originally developed using NASA funding, within NASA and its affiliates to minimize unnecessary government investments.

Summary of Current Commercial Space Research

WCSAR's commercial space research program was very productive this year with two International Space Station (ISS) missions accomplished. Both experiments have terrestrial applications through the development of new and enhanced food, medical, and other plant-derived products and enable future space exploration by providing renewable food sources and environmental controls.

The first mission was the second Arabidopsis seed-to-seed experiment conducted jointly with Space Explorers, Inc., a WCSAR industry partner, and flew onboard the ISS Stage 8A. The objectives of this experiment were to 1) validate plant life support technologies used in the Advanced Astroculture™ (ADVASC) payload, 2) produce the second generation of seeds harvested from the first generation of seeds harvested from a previous mission, and 3) conduct a gene expression analysis to determine whether microgravity may alter Arabidopsis gene expression levels. Despite a loss of soil moisture control which caused high humidity in the growth chamber, a significant amount of science was recovered. At the end of the mission, living tissues (at two different stages) were harvested and a considerable amount of the 2nd generation space seeds were produced from the surviving plants.

The second mission, the first soybean seed-to-seed experiment, flew onboard the ISS Stage 9A. The objectives were to 1) demonstrate that controlled environment and plant growth controlled technologies developed by WCSAR were suitable for major agricultural crops, such as soybeans, to grow and to produce seeds in space, 2) investigate whether unique phyochemical properties will be found in soybean seeds produced in space, and 3) study whether newly found traits are genetically stable, meaning whether they can be inherited by the next generation. The payload performed very well without any anomalies during the mission. The environmental conditions of the plant chamber were precisely controlled at their set-points. The mission was successfully accomplished and 100% of the science objectives were achieved.

Supporting NASA's Mission

Ways in which WCSAR supports NASA's mission include, but are not limited to, the following:

To Understand and Protect Our Home Planet

Plant growth research in microgravity can enrich lives on Earth through the development of new and enhanced food, medical, and other plant-derived products

To Explore the Universe and Search for Life

Plant growth research in microgravity has direct and indirect applications to provide the next generation of space explorers with renewable food sources and new environmental control technologies

To Inspire the Next Generation of Explorers

Orbital Laboratory™, jointly developed by the Space Explorers, Inc. (SEI) and WCSAR is an internet-based commercial software suite serving as a curriculum for the enhancement of students' math and science capabilities. It creates a virtual space environment, using data obtained from previous and future shuttle/International Space Station (ISS) experiments for students in grades 4 to 12 to design, conduct, and analyze plant biology experiments.

Employ graduate students in research and hardware development

Metrics

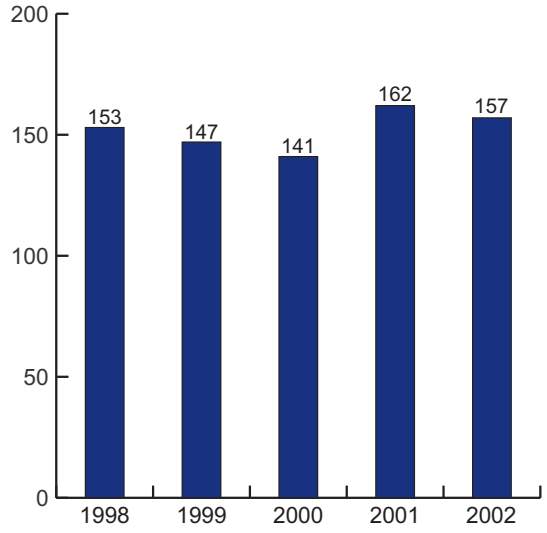
Industry partners are the cornerstone of NASA space commercialization activities. When many different types of businesses, both small and large, become involved in using space for their purposes, a broad industrial base develops that understands the benefits of using space and microgravity. This broad base forms the foundation for future commercial activities in space, from research and production on private space platforms to the private launch services needed to reach those opportunities. In this way, NASA space commercialization works with industry today to help them develop the technology, products, and services they need for their future.

Growing this industrial base is one goal and function of the SPD program and its Research Partnership Centers. While NASA provides the Centers with their base funding for operations and flight hardware development, the remainder of their funds must be sought from other sources, primarily through partnerships with industry on commercially-driven research projects.

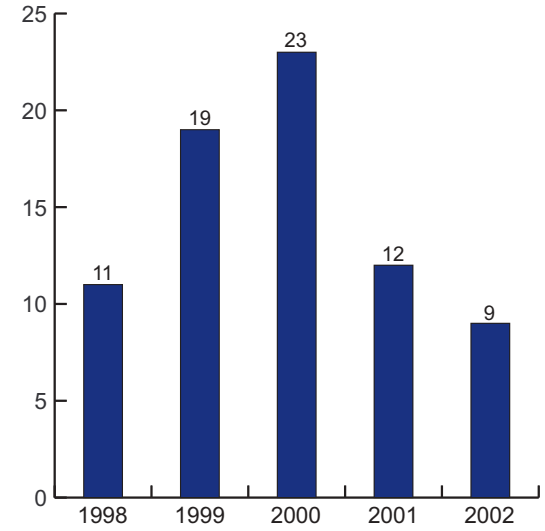
Because industry funds the majority of the research, jointly performs the research, pays for a portion of the launch costs, and brings the resulting products or services to market, commercial intellectual property and proprietary data, techniques, and systems are protected.

While ground-based research is an important part of any research program, it is the access to space and microgravity that allows NASA's industry partners to accelerate their research. By making use of these unique environments, investigators can distinguish events and phenomena that normally are masked by gravity, gather data quickly and precisely without the interference of gravity, and do processing not practical or possible on the Earth's surface.

Industry Partnerships

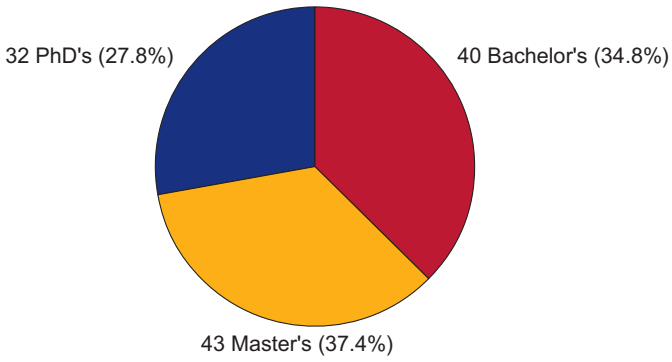


Licensing / Equity Agreements

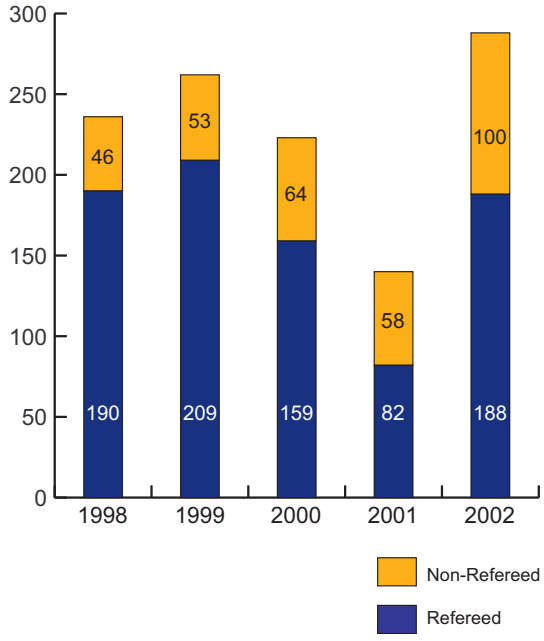


The SPD program works to provide its industry partners with access to space and/or microgravity through a variety of means. Drop tubes and towers can provide 1 - 5 seconds of microgravity, KC-135 aircraft can provide 20 - 30 seconds of microgravity at the top of a parabolic arc, the Shuttle can provide up to two weeks of microgravity and/or space, and the International Space Station will provide months of opportunity for investigators. All available flight opportunities are being utilized. SPD is prepared to take advantage of any additional flight opportunities that arise.

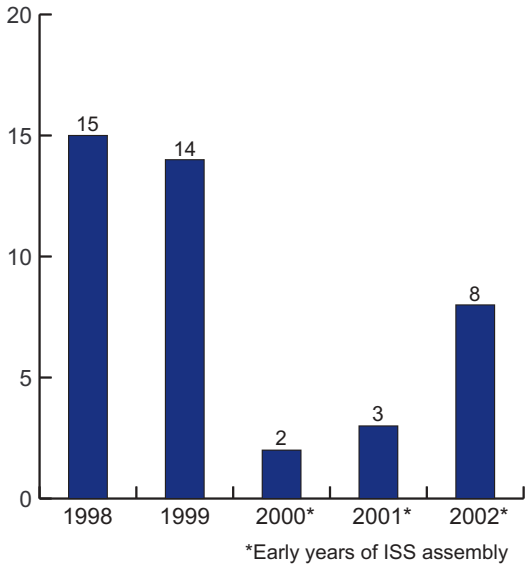
DEGREES AWARDED (115 TOTAL)



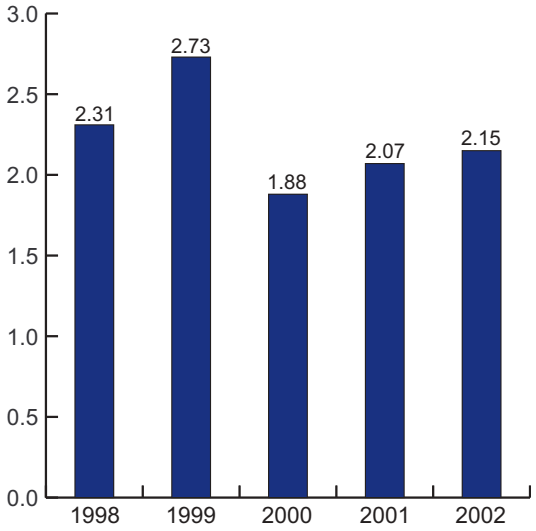
PUBLICATIONS



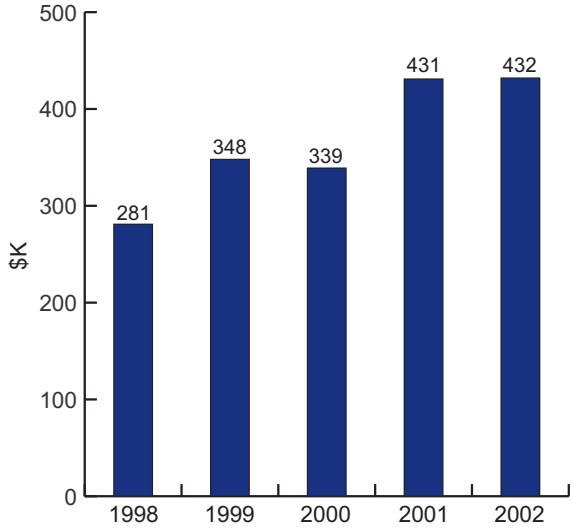
PAYLOADS FLOWN



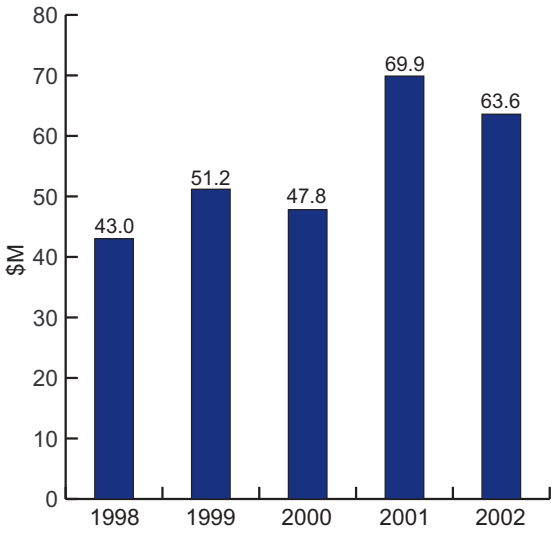
Ratio of Non-NASA Cash and In-kind to SPD Funding (inluding ISS)*



Average Non-SPD Investment Per Industry Partnership*



Non-SPD Funding



*Numbers have been adjusted from previous years to include ISS funds, which are now part of the Office of Biological and Physical Research (OBPR) program.

Financial Summary

The following information is a financial summary of all 15 Research Partnerhsip Centers for Fiscal Year 2002.

Cash and In-kind

SPD Total Funding	$29,646,000	
Other NASA (Field Centers)	$4,250,842	
Non-NASA Cash		
Industry Cash	$5,788,000	
Other Cash	$27,224,658	
Industry In-Kind	$27,342,000	
Other In-Kind	$3,327,000	
Total Program		$97,578,500

Leveraging Ratio

Non-NASA Cash and In-kind to SPD Funding (inluding ISS)	2.15
Non-NASA Cash and In-kind to SPD Funding (excluding ISS)	4.21

Economic Development

Total Number of Industry Partnerships	157

Partners and Affiliates

The following is a selected list of industry partners and other affiliates. Not every company that partners wants to let its competition know about their activities. For that reason not every partner is included. It may be worth considering that one's competition might be one of those not listed.

ACIPCO
Advanced Modular Power Systems
AERA, Inc.
Affymetrix
Allison Gas Turbines
American Ag-Tec International, Ltd.
American Foundry Society
Amgen
ANALIZA, Inc.
Anter Corporation
APEX-ECLIPSE Corporation
Applied Optoelectronics, Inc.
ArQule
Astropower, Inc.
Athersys Company, Inc.
Beeworks
BellSouth Telecommunications
BioCryst Pharmaceuticals, Inc.
Bionetics Corporation
Boeing Corporation
Boeing Space Systems
Brimrose Corp. of America
Bristol-Myers Squibb
British Aerospace Corporation
Broad Reach Company
Busek Co. Inc.
Calbiochem
Canton Bio
CEC
Cenetec
Chevron Research
Chiron Corporation
ChK Group
CIBCO, Inc.
Cisco Systems
Citation Corporation
Citation Southern Aluminum
Compaq Computers
Composite Technology Developers, Inc.
Computer Motion
CoorsTek
Critical Care Innovations, Inc.
Customer Manufacturing and Engineering
Cyrano Sciences
Diversified Scientific, Inc.
Dupont
Durel Corporation
ENTECH, Inc.
Environmental Research Institute
Essential Research, Inc.
EXXON
Federal Mogul
Fluorogen, LLC
FogCo (formerly Arizona Mist)
GE Education Foundation
GeneMachines, Inc.
Global Telemedicine Group
Global Thermoelectric
Goldens Foundry & Machine
Goodrich Corporation
Guigne International, Ltd.
Halliburton Corp.
Harmony Castings Co.
Herman Williams Co.
Herzog Hart
Hewlett-Packard
Honeywell Science Center
Hughes Network Systems
Hughes Space & Communications
Ibbex, Inc.
IGP Photonics Corp.
Imperx
In Space Propulsion, Ltd.
Informed Diagnostics, Inc.
Infrared Fiber Systems, Inc.
Innovative Scientific Solutions, Inc.
In-Pod, Inc.
Integrated Micro Sensors
Intek, Inc.
Intermet Columbus Foundry
International Flavors and Fragrances, Inc.
Invitrogen Corporation

Ionwerks, Inc.
Iridex Corp.
Isis Pharmaceuticals
ITN Energy Systems, Inc.
Laempe+Reich Inc.
Lockheed Martin Astronautics, Inc.
Los Gatos Research
Louisiana Veteran's Research and Education Corporation
Lucent Technologies
Makel Engineering
Materials Electrochemical Research Corp.
Medtronic
Memorial Hospital in Gulfport
Metal Oxide Technologies, Inc.
Microcool Div. of Nortek (formerly EEC)
Molecular Simulations Inc.
MONSANTO
Morgan Optics (formerly Trex Enterprises Corporation
Motorola
Nanoscale Materials Inc.
Nektar Therapeutics (formerly Shearwater Polymers, Inc.)
Neptune
Next Generation Health Systems
Northrup Grumman
Oculus Pharmaceuticals, Inc.
Olympus America
Opto-Knowledge Systems, Inc.
Orbital Sciences Corporation
Paradigm Genetics
Pfizer
Pharmacia Animal Health
Pioneer Hi-Bred International, Inc.
Plum Creek Timber Company
Polaroid Corporation
Producers' Natural Processing, Inc.
Prototek, Inc.
QRS Technologies
Radiance Technologies, Inc.
Rice Systems, Inc.
Rush Enterprises
SAF Agri
SAIC Corporation
Sanderson Farms, Inc.
Schering-Plough Research Institute
Sharp Laboratories of American, Inc.
Siemens
Southern Regional Research Center
Space Explorers, Inc.
SpaceHab Inc.
St. Joseph Hospital
Stahlschmidt & Maiworm
StelSys, LLC.
Sulzer Biologics, Inc.
Sulzer Orthopaedics
SuperVision
Taconic, Inc.
TDA Research
Team Encounter
Technology International Inc.
Telcordia Technologies
Texas Components Corp.
The Jackson Laboratory
Thermacore
Trex Enterprises
Tyco-U.S. Surgical
United Technology Research Center
UPM-Kymmene
Vasocor
Vermont American Inc.
Virginia Biosciences Research Center
Virginia Biotechnology Research Park
Virtual Drug Development Institute, Inc.
Weyerhaeuser
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Medical Informatics and Technology Application Consortium (MITAC)

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