SPACE PRODUCT DEVELOPMENT

1999


SPACE PRODUCT DEVELOPMENT
SPD
Space For Business to Grow

1999 has proven to be an outstanding year for Space Product Development. Recent products and services resulting from investigations co-funded and conducted by industry are solid evidence for SPD's growing program success.

Industry investment in space and microgravity research is at an all time high. We flew 10 commercial payloads, comprised of more than 25 industrial investigations, during this Fiscal Year. Industry has reported considerable, and in some cases remarkable, success from these cooperative missions. These achievements, which will be discussed in the following pages, may provide new insights and introduce improvements to everyday life in the form of new products, treatments and services.

While our successes are noteworthy, and are clearly bringing the benefits of space down to Earth, the greatest excitement lies ahead. During the past year the foundation elements of the International Space Station were successfully launched and assembled. While the capabilities of research on this platform are quite limited at this time, we look forward to the ever increasing capability and flight opportunities as the assembly progresses. By the time the station's assembly is complete we will realize the rewards of three continuously operating space laboratories, as well as external platforms for technology development.

The Space Product Development program is determined to maximize these and other opportunities that lie ahead. We are working with industry to make maximum use of station accommodations, and to expand commercial operations on all flights. We are dedicated to NASA's goal of reducing the cost to orbit, and are supportive of efforts by both NASA and private industry to bring about affordable, reliable, and frequent access to space. We are also dedicated to making our operations highly efficient in order to leverage our funding to the greatest extent possible, thereby allowing industry to obtain the most value for their investment in the program.

Apart from these efforts, we have increased our attempts to educate the public and industry about the Space Product Development program. This Annual Report is designed to help people recognize the benefits of past research in space, and also to help industry understand the positive impact such research can have on its bottom line in the near future. Our new WWW site is now online at http://commercial.nasa.gov and efforts to reach out to industry are also being made at trade shows and similar venues.

As you read about the successful research and product development in the pages that follow, I want you to know that we are already working hard to ensure that the approaching space station era realizes its fullest potential.

Mark Nall
Manager, Space Product Development

materials

Brush Wellman Incorporated successfully produced the world's largest aluminum-beryllium casting with the assistance of ground-based casting data and computational models developed by the Solidification Design Center. This alloy is very lightweight, making it useful in a number of aerospace applications.

A special optical detector developed by the Space Vacuum Epitaxy Center may offer the gift of sight to people with a variety of eye problems. The detector is designed to be implanted on the back wall of the eye, replacing natural sensors damaged by disease or accident. The detector converts light into electrical signals in much the same way as rods and cones operate in a healthy eye, and the optical nerve then picks up those signals. Preliminary testing has been successful and efforts at commercial development are underway.

The Ford Motor Company has used materials data supplied by the Solidification Design Center to design new, high-quality sand molding processes for creating precision automotive parts. This type of work is also being done by the Solidification Design Center for ALCOA and Howmet Corporation in order to cast parts that are more reliable and yet lower in cost.

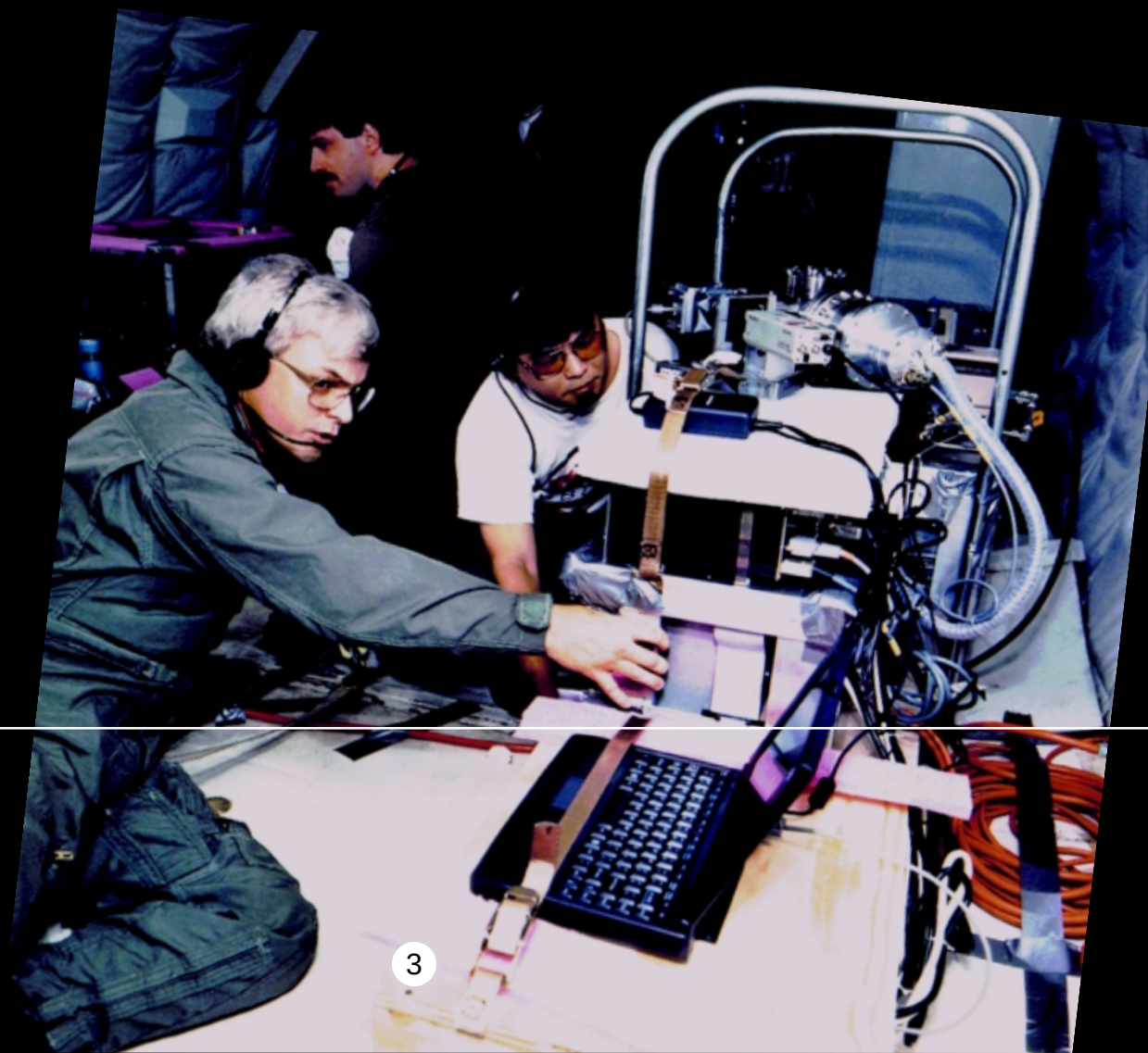
Metal Oxide Technologies is commercializing a new technology, developed by the Space Vacuum Epitaxy Center, for the fabrication of High-Temperature Superconducting (HTS) wires using oxide thin films. HTS wires can carry extremely high currents with little loss, allowing the size of transformers to be reduced by approximately half and eliminating the need for oil cooling. This, in turn, eliminates the environmental concerns associated with transformer fires, oil spills, and PCB contamination. The HTS technology has been licensed and a pilot plant for producing HTS wires for use in power line transformers is expected to be operational by 2001.

International Stellar Technologies, Inc and the U.S. Air Force are developing new solar cells created by the Space Vacuum Epitaxy Center. These unique cells have efficiencies comparable to conventional Indium Phosphide solar cells, but they are thinner, more resistant to radiation, and are nearly as efficient at the end of their life as at the beginning. These improved cells could result in smaller, more effective solar arrays.

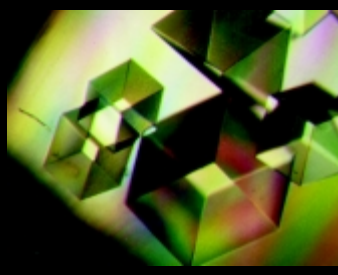
Optical components are considered an essential part of future advanced computers. Such systems will make possible the rapid storage, transmission and processing of massive amounts of data. Non-Linear Optical (NLO) materials, investigated through the Consortium for Materials Development in Space, may allow up to a three-fold increase in optical storage capacity with data switching speeds of one-trillionth of a second and optical data processing at near the speed of light.

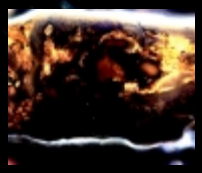
Applied Optoelectronics Incorporated will help commercialize a mid-infrared semiconductor laser that operates at room temperature. The Space Vacuum Epitaxy Center optimized the design and fabrication of the laser, which has many potential applications, such as environmental monitoring and space exploration.

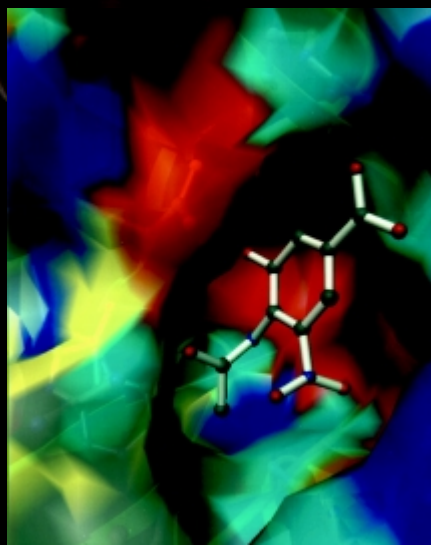
ZBLAN Fiber Optic cables, made of the elements Zirconium, Barium, Lanthanum, Aluminum, and Sodium, may be more than 100 times more effective in transmitting data than traditional silica fibers. NASA investigations, with commercial partners Lucent Technologies and Infrared Fibers, Inc., may lead to improvements in optical data transmission, medical surgery, fiberoptic lasers, optical power transmission, and fiberoptic gyroscopes.



biotech







Two new types of cameras that were developed by the Center for Commercial Applications of Combustion in Space and Roper Scientific for combustion research are now being applied to the field of medicine. A double-image camera and a gated integrator camera are being marketed in the multi-billion-dollar medical imaging field. This new technology will allow weak images to be pulled from strong backgrounds, such as when tumors have the same general color and lighting as surrounding tissue.

CMC commercial partner BioCryst, Inc. signed a teaming agreement with Johnson & Johnson to develop and market a drug designed to inhibit the neuraminidase protein, an enzyme crucial to the reproduction of the flu virus. Crystals grown on Earth and in space supported the development of drug candidates that have performed strongly in pre-clinical trials against both influenza A and B. Clinical trials should be completed soon.

A cancer drug, Proleukin, developed by Chiron Corporation and supported by collaborative research with BioServe Space Technologies, has been approved by the FDA for use in treatment of renal cell cancer and metastatic melanoma. In addition, Proleukin is being examined in FDA phase III human clinical trials for treatment of leukemia and HIV infection.

Bone loss from accident or illness is a serious problem, especially since current bone replacements can end up being replaced multiple times during a patient's life. A ceramic-metal composite is one possible bone replacement that, unlike many conventional therapies, is highly porous, allowing blood vessels, nerves, and even bone to grow through and around it. The Center for Commercial Applications of Combustion in Space has successfully synthesized this product using Self-propagating High-temperature Synthesis (SHS) reactions.

Chiron Corporation is examining Myotrophin, a drug currently in FDA phase II human clinical trials for treatment of osteoarthritis. Chiron is evaluating Myotrophin as a potential treatment for other skeletal disorders, since flight research with BioServe Space Technologies has indicated its effectiveness in preventing bone loss resulting from spaceflight in rats.

The antibiotic actinomycin D is often used in conjunction with cancer treatments. Production of actinomycin D by microorganisms was 75 percent higher in microgravity on STS–95 than in comparable ground control experiments, providing Bristol-Myers Squibb, Industry Partner of BioServe, with new insights that may improve ground-based production.

The Center for Macromolecular Crystallography, in collaboration with The Hauptman-Woodward Medical Research Institute, grew large crystals of human insulin on STS–95. Scientists have never been able to grow crystals of this size on Earth, despite years of efforts. These larger, space-grown crystals yielded high-quality data, and will allow the electrostatic (as opposed to geometric) crystal structure to be determined. This determination will be extremely useful in improving insulin formulations for the treatment of diabetes.

Wisconsin-based Quantum Devices, Inc has advanced photodynamic therapy, used to treat tumors without damaging surrounding tissues, by making improvements in the Light Emitting Diodes (LEDs) developed for the Wisconsin Center for Space Automation and Robotics. The LEDs are used in conjunction with light sensitive chemotherapy drugs for cancer treatment. Since the LED unit can be purchased for a fraction of the cost of a laser, this work has the potential to help reduce the cost of cancer treatment while making it more effective. The LEDs also have been used this year to help treat more than 300 cases of skin cancer.

Courtesy Agricultural Research Service, USDA

agribusiness

Courtesy Agricultural Research Service, USDA

Courtesy IFF, Inc.

Roses have more than meets the nose: International Flavors & Fragrances, Inc., an Industry Partner of the Wisconsin Center for Space Automation and Robotics, reported detecting an entirely new scent from a rose during research on STS–95 based on their analysis of the flight data. This finding potentially may open many new doors for the multi-billion dollar-a-year "flavors and fragrances" industry.

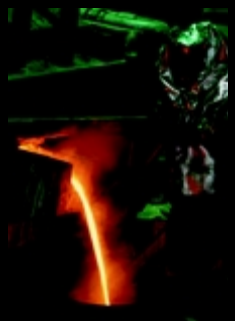
A gene-transfer experiment by Wisconsin Center for Space Automation and Robotics Industry Partner Rapigen, LLC and its partners showed that microgravity provided at least a 10-fold increase in the successful transfer of traits to soybean seedlings over ground-based one-in-a-thousand success rates. This finding could improve U.S. soybean production, since the USDA estimates more than 70 percent of the soybean seeds planted in the United States are genetically engineered.

Courtesy Agricultural Research Service, USDA

The production of minitubers—dime-sized potatoes used as seeds for larger crops—is a business that is anything but small potatoes. Unlike other seed crops, seed potatoes are bulky and heavy, and most countries limit their import as a means of controlling plant disease. In addition, the normal process of producing new, disease-free seed potatoes can literally take years to bear fruit. Yet many countries need improved seed potatoes now, since as much as 85 percent of current crops are diseased to the point where they are not fit for human consumption. American Ag-Tec International, Ltd. is making use of the environmental and growth systems developed for use by the Wisconsin Center for Space Automation and Robotics to address this critical problem.

Courtesy American Ag-Tech International

quotes from industry



"Our collaboration with NASA not only puts our researchers in the forefront of science, but also gives us the opportunity of being first in our field to develop major new technologies and products." Ray Lam, Natural Products Research, Bristol-Myers Squibb

"The NASA and Auburn University-led research project on turbine blade castings has enhanced our capabilities, helped us realize a cost savings, and accelerated the development cycle for rocket hardware." Dr. Thomas Tom, Director of Advanced Technology, Howmet Industries.

"Partnering with NASA offers unique research opportunities to improve production methods used in the foundries here on Earth to enhance the quality of castings. Advanced research into new processes will expand the utility of castings by making them more affordable and reliable, and expands their utility." Dr. Joe Santner, Director of Research, American Foundrymen's Society.

"The fact that fragrance molecules do change in proportion to one another promises to lend a greater dimension to future fragrance research and the possibility of using microgravity to create new fragrance entities, or, for that matter, any chemical products including possibly pharmaceuticals, that the plant produces." Eugene Grisanti, Chairman and CEO, International Flavors and Fragrances, in reference to a commercial investigation on STS–95.

"The level of genetic transfer [in soybean seeds] was way beyond our expectations." Ray Bula, Principal, Rapigen LLC, in reference to a commercial investigation on STS–95.

"We've been involved in space-based research with BioServe for over a decade and the investment has been well worth it." Jim Carbonari, CEO, PentaPure

"The key to the commercialization process was NASA's continued support of SVEC and the fact that Dr. Alex Ignatiev, one of the world's foremost experts on epitaxial growth and a colleague of Dr. Paul Chu, was here in Houston, and his team eventually solved the deposition technology issues." Louis Castellani, President, Metal Oxide Technologies, Inc.

"I was initially quite skeptical about the possible benefits that might come from these efforts but I have clearly seen the advantages that this unique environment has to offer in the area of protein crystal growth. …The results from these space experiments displayed a dramatic improvement in the data and this information has allowed us to better understand the interaction of a pharmaceutical compound with the insulin molecule." Dr. Herbert A. Hauptman, President, Hauptman-Woodward Medical Research Institute, Inc.

"My involvement in five previous space shuttle-based microgravity protein crystallization studies leads me to conclude, simply, that the microgravity environment offers the potential of enormous benefits for protein crystallization. …The findings of this work have indicated that microgravity crystallization offers enormous potential for improving protein crystal growth, and therein lies the reason for my support." Dr. John A. Thomson, Head of Biophysical Chemistry, Vertex Pharmaceuticals, Inc.

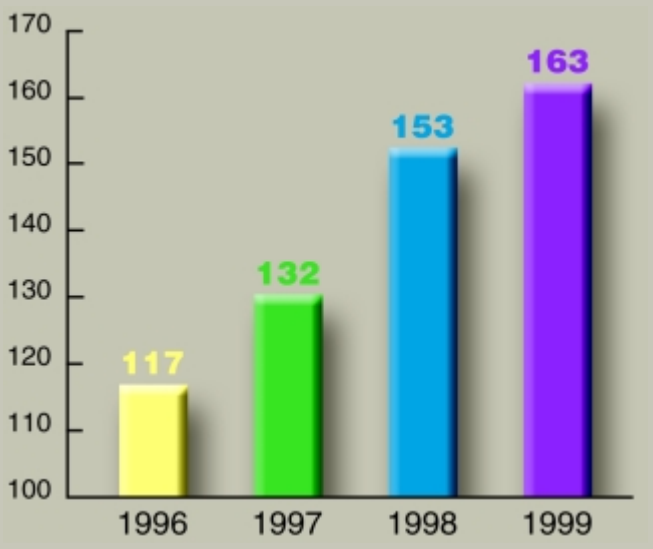
affiliates and

Industry Partners are the cornerstones of the Space Product Development program and space commercialization. When many different types of businesses, both small and large, become involved in the space program, a broad industrial base develops that understands the benefits of space and microgravity research. This broad base forms the foundation for future commercial space activities, and willingness to invest in space research will go up as the cost of going into orbit comes down.

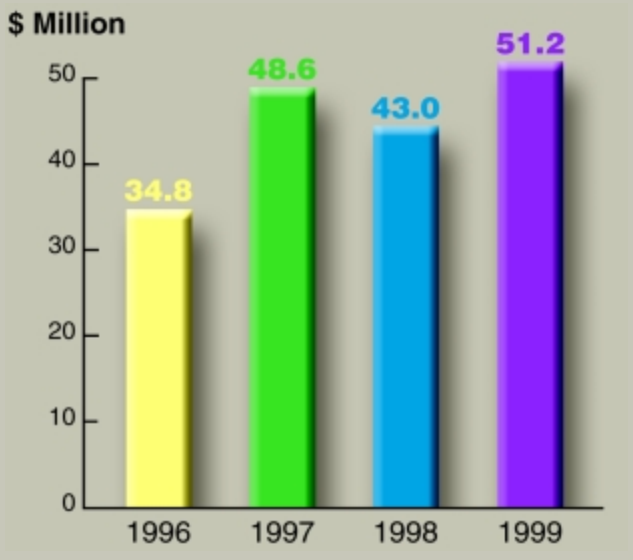
Growing this industrial base is one goal and function of the SPD program and its Commercial Space Centers. While NASA provides the Centers with their base funding for operations, the remainder must be sought from other sources, primarily through partnerships with industry on research projects.

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. This is what helps set the SPD program apart from traditional science operations and technology transfer efforts. SPD works with industry today to help them develop the technology, products, and services they need for their future.

Two measures of the success of the program are the number of affiliates and the amount they invest into the program.

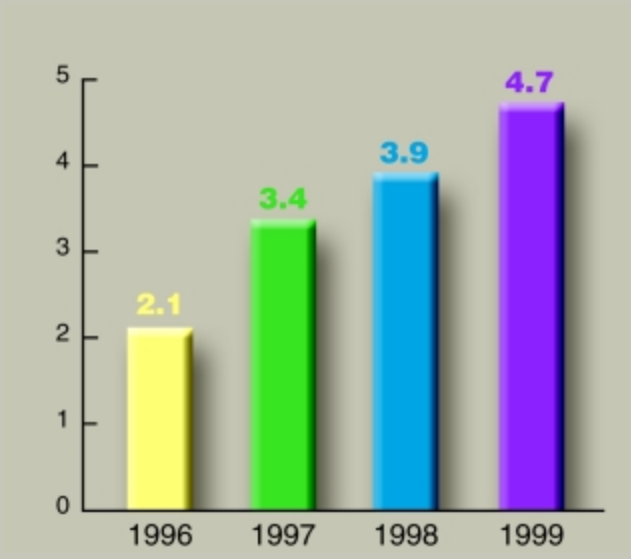


Industry Affiliates

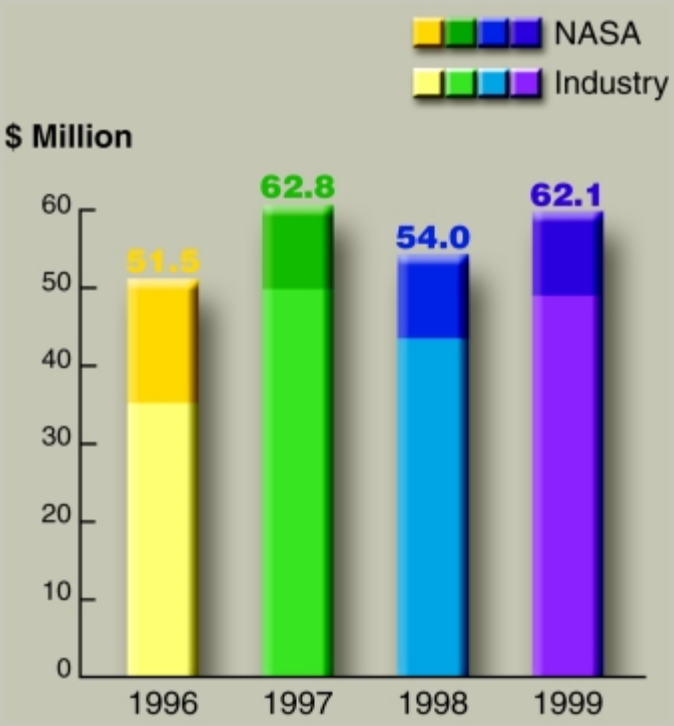


Non-NASA Funding

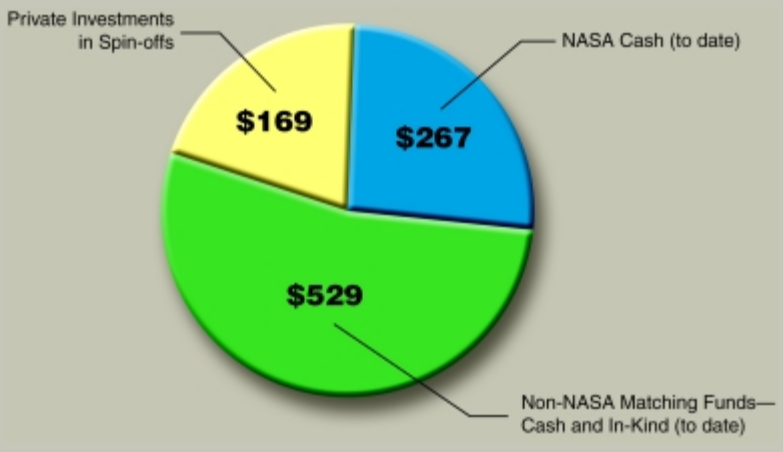
leveraging



Ratio of Industry Co-Funding to NASA Funding

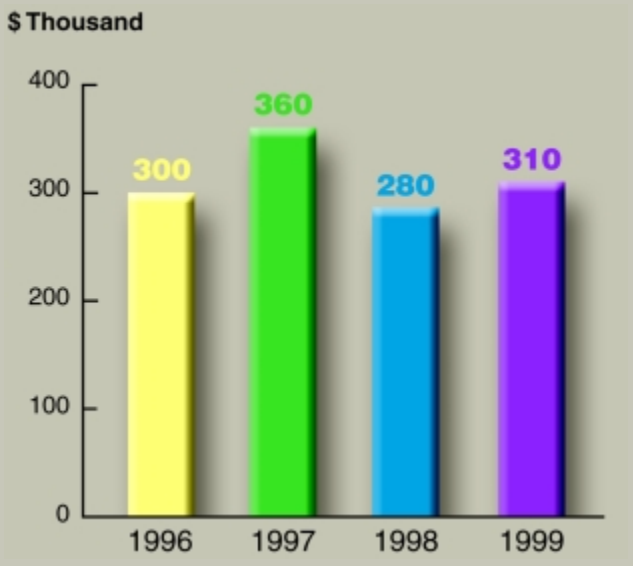


CSC Leveraging



Total Investment (Cash & In-Kind) **in CSCs and Spinoffs to Date in $M**

Total = $965 million

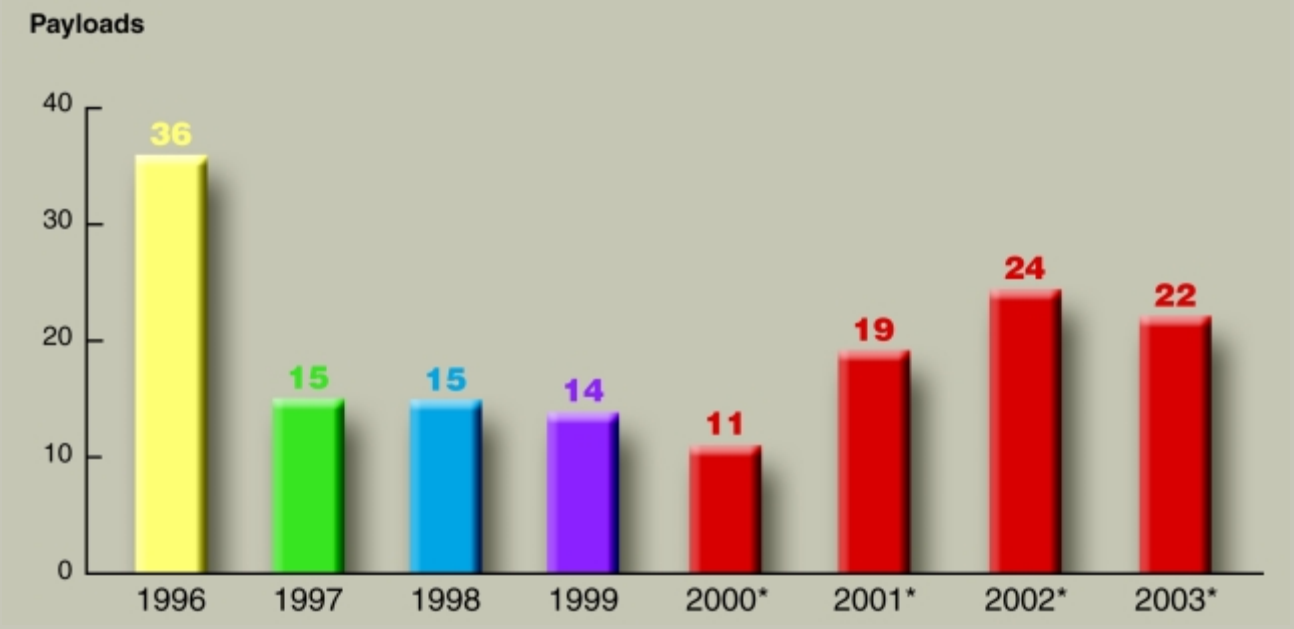


Average Industry Investment Per Participant

payloads

While ground-based research is an important part of any research program, it is the access to space and microgravity that allows our Industry Partners to advance their research efforts. 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.

The Space Product Development program works to provide its 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 an arc, the Shuttle can provde up to two weeks of microgravity and/or space, and the International Space Station will provide months of opportunity for investigators. Even as flight opportunities have temporarily lapsed to support construction of the International Space Station, SPD is working to increase commercial flight opportunities, and to help with efforts to commercialize the station.



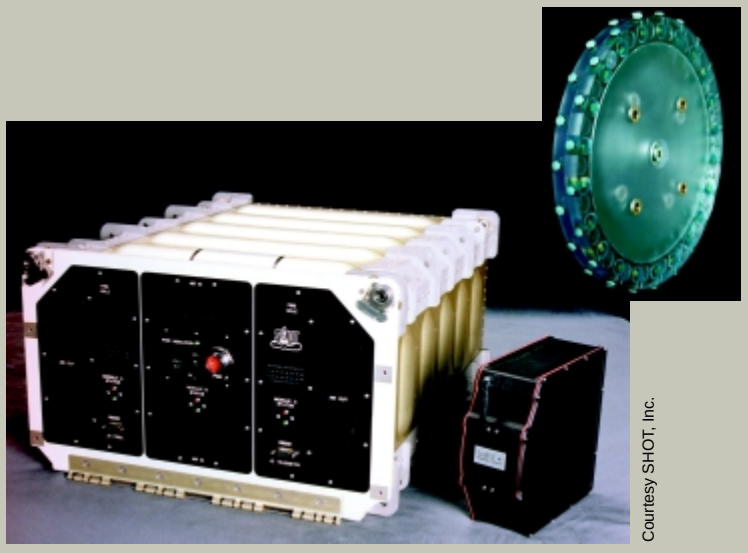
*Figures in red indicate current projections.

flown

These numbers only tell a part of the story. Much of the flight hardware developed by the Commercial Space Centers can carry multiple experiments, often covering different areas of research. So while only 14 commercial payloads were flown in FY99, commercial companies flew more than 25 experiments on those payloads. These commercial payloads include:

ADvanced SEParation ▶

The ADvanced SEParation commercial payload, developed privately by Space Hardware Optimization Technology (SHOT), Inc makes use of major advances in separation technology to support a variety of experiments using experiment cassettes that can be inserted and processed. On STS–95, the payload supported the Phase Partitioning Experiment, the Microencapsulation of Drugs experiment, and the Hemoglobin separation experiment.



Courtesy SHOT, Inc.

ADSEP Hardware

The ASTROCULTURE™ Hardware

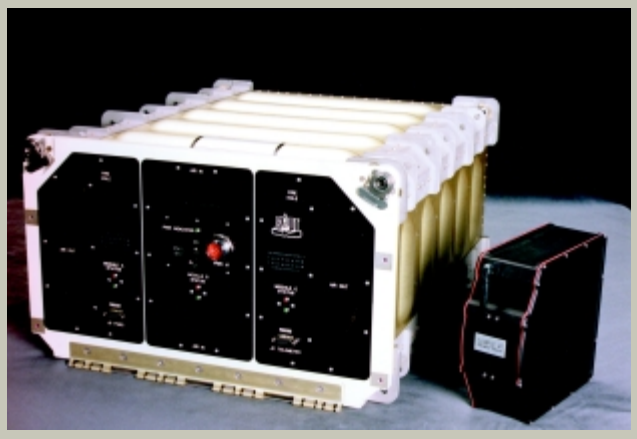
◀ ASTROCULTURE™

ASTROCULTURE™ is a commercial plant growth and experiment facility that supports a wide range of commercial investigations, from plant growth to the production of new plant types. On STS–95, ASTROCULTURE™ supported the Space Rose experiment and an investigation to see if microgravity could benefit the transfer of genetic traits to plants.

payloads

Biodynamics and Space Cell Culture (BioDyn) Bioreactor ▶

The BioDyn Bioreactor was developed jointly by Synthecon Incorporated, Space Hardware Optimization Technology (SHOT), Incorporated, and the UAH Consortium for Materials Development in Space to use a rotating bioreactor concept and the UAH bioprocessing modules to support a variety of cell and tissue culturing experiments. On STS–95, the BioDyn payload supported investigations on recombinant proteins, cell death factors, tissue engineering of heart patches and bone implants, anti-cancer drugs, and cancer (leukemic) cell suppression factors and gene regulation in microgravity.



BioDyn Bioreactor
Courtesy SHOT, Inc.

A manually activated GAP on orbit.

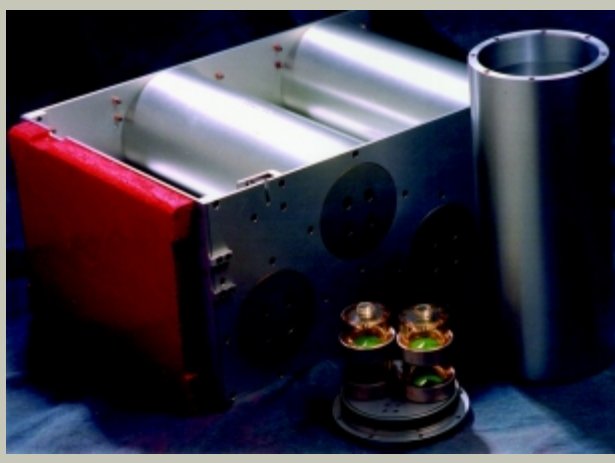
◀ Commercial Generic Bioprocessing Apparatus (CGBA)

This unique facility was designed to support a large number of small, sophisticated bioprocessing investigations using a special "microgravity test tubes" called a Fluid Processing Apparatus (FPA). Each FPA is a glass barrel containing several chambers separated by rubber stoppers. Eight FPAs are placed together in a Group Activation Pack (GAP), which allows all of the experiments to be started simultaneously by an attached motor drive. Eight GAPs, or similar sized payloads, can be stored in a single CGBA temperature-controlled locker. On STS–95, CGBA supported eight research efforts: Protein crystal growth, antibiotic production, bacterial growth and control, cell separation, plant products, plant science, plant research, and aquaculture.

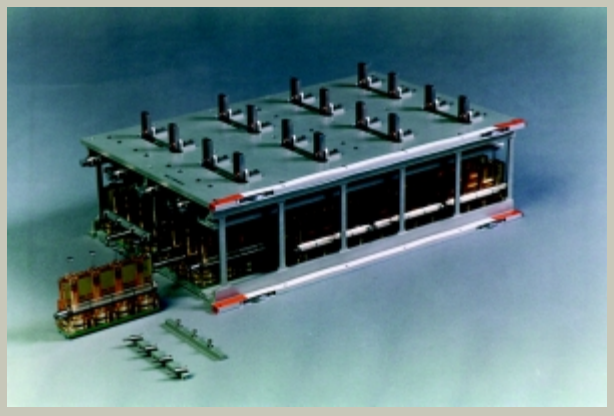
flown

Protein Crystallization Facility ▶

The Protein Crystallization Facility supports large-scale commercial investigations with protein crystallography. Scientists can determine the structure of proteins by studying crystals, such as those produced by PCF. That information can be used in structure-based drug design, allowing for more effective treatments with fewer side effects to combat a variety of diseases. On STS–95, this facility supported research on human insulin.



Protein Crystallization Facility
Courtesy Center for Macromolecular Crystallography



Commercial Vapor Diffusion Apparatus
Courtesy Center for Macromolecular Crystallography

◀ Commercial Vapor Diffusion Apparatus (CVDA)

This facility uses a version of the “hanging drop” method to grow protein crystals: two solutions are mixed into a liquid drop that “hangs” in the growth chamber. As part of the solution making up the drop migrates to a special material surrounding the chamber, a crystal or crystals form in the drop. As many as 128 individual crystal growth investigations can be performed in a single CVDA unit. On STS-95, this facility supported research that included efforts to grow crystals of HIV-1 Protease Inhibitor, Glycogen Phosphorylase A, and NAD Synthetase.

Commercial ITA Biomedical Experiment ▶

This facility, developed privately by Instrumentation Technology Associates (ITA), Incorporated, provides the support and resources needed to perform multiple biomedical experiments, from protein crystallography to the microencapsulation of drugs. The facility fits in two Commercial Refrigerator/Incubator Modules and allows a mixture of hardware to be used, including Liquids Mixing Apparati, Dual Materials Dispersion Apparati, and a Protein Crystallization Facility. On STS-95, the facility supported research on protein crystal growth, the microencapsulation of pharmaceuticals, and student research as a part of ITA’s education efforts.

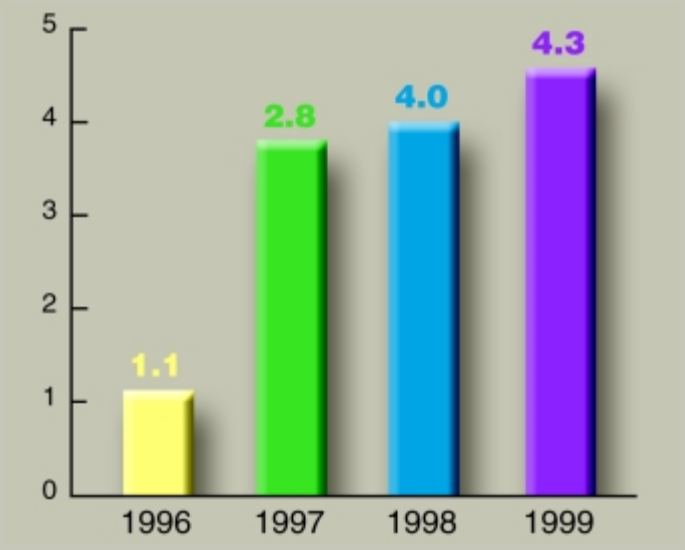
Commercial ITA Biomedical Hardware, credit:
Courtesy ITA, Inc.

patents, publications & students

Payloads, flight missions, and commercial partners are important elements of success for the Space Product Development program. Other measures of SPD's success are the number of patents filed by or through the Commercial Space Centers, the number of publications about the research or systems, and the education of the students taking part in commercial research ventures.

Of these items, patents represent the most significant measure of the innovations being produced through commercial space and microgravity research. As new products, technologies, and services are developed, the Commercial Space Centers and industry are working together to ensure that these efforts are both protected by law, and made available to U.S. Industry.

Papers are more than simply an announcement of what has been done. They are a way of spreading knowledge, and inviting academic and industry dialog on the work that has been done. Through this feedback, the work is strengthened and validated even as it is being presented.

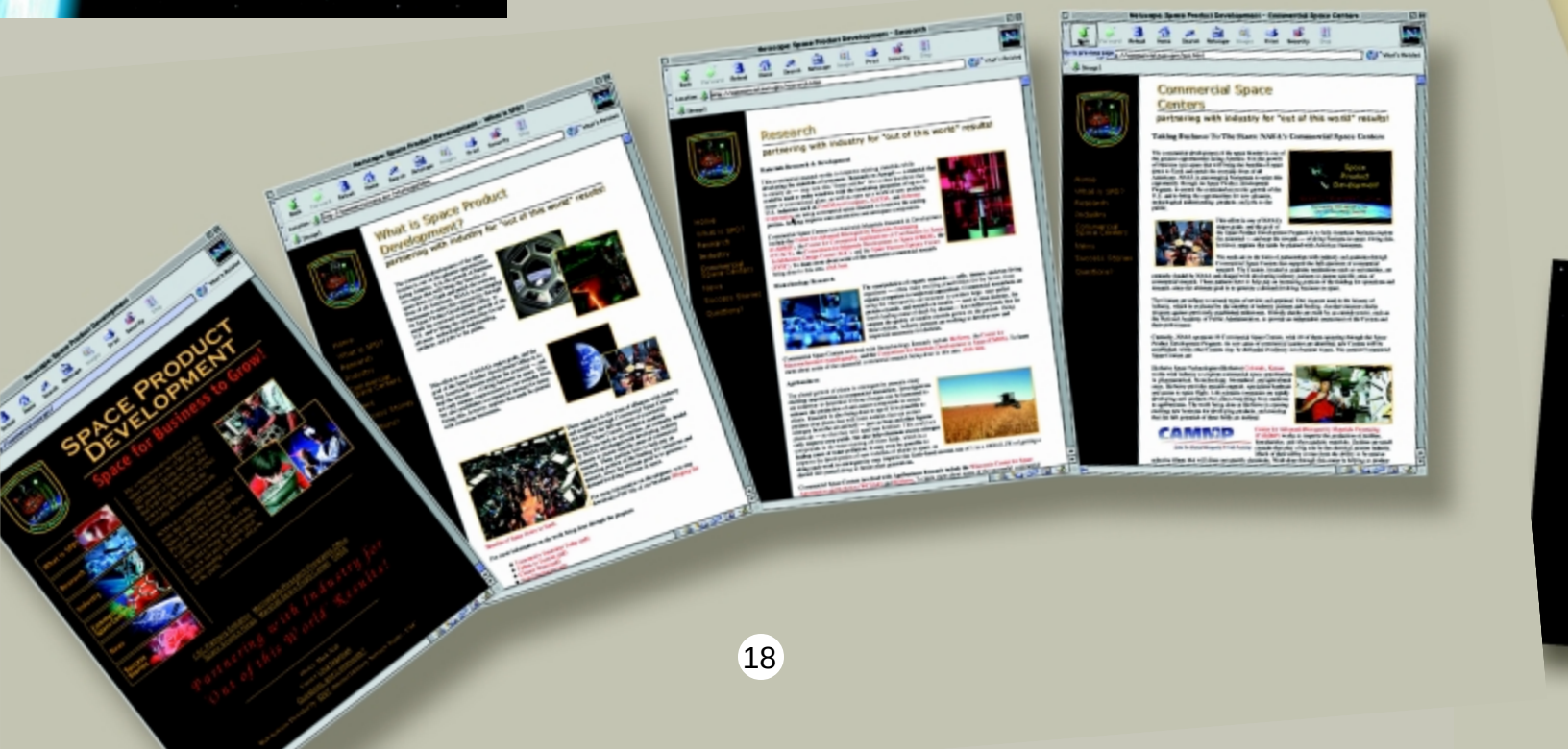


Ratio of Refereed to Non- Refereed Publications

Student involvement is critical for the future viability of space commercialization. Attracting students to science and science-business careers will lead the next generation to create technological advances that will help maintain the U.S. economy and will provide new products and services to industry, academia, and the public. As a result, the Commercial Space Centers employ students, providing them with research and operations experience. Some of the private companies involved, such as Instrumentation Technology Associates, Inc., also have established their own privately funded educational outreach efforts.

operation

As a part of major reorganizations throughout NASA in 1999, the Space Product Development Program office was restructured and staffed to provide improved oversight of, and support to, the operations and projects at the Commercial Space Centers. This includes support to the Centers in completing procedures required for space flight acceptance of research hardware and experimental processes. The SPD staff not only serve in the traditional oversight role but also work intimately with the Centers to develop a thorough understanding of their commercial directions. Each member of the staff serves as both a strong critic and an ardent advocate of the commercial initiatives. The staff consists of experienced managers who are committed to enabling industry to achieve the greatest benefit from its involvement in space research.



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Outreach was another area of improvement for the program. The services of a person experienced in scientific and commercial communications was secured to create an outreach program for Space Product Development. During FY 1999, a slogan (Space For Business To Grow), a cutline (Partnering With Industry For Out Of This World Results), and a new logo were created for the program. A WWW site (http://commercial.nasa.gov) was established, tested, and brought online. Currently, the site is experiencing steady growth in terms of hits, and efforts to grow visitations are underway. A proposal for an interactive educational site, focusing on basic business operations and scientific and technical business development, currently is in process.

Brochures and other developed outreach tools were combined with participation in trade shows and conferences to expand outreach to industry and the public. These shows, featuring representation from the Commercial Space Centers and the Industry Partners, allowed positive outreach to be established with more than 23,000 people, and stimulated interaction between 15 potential partners and the Centers, and provided a forum for feedback and continuous improvement of existing processes and and the development of new concepts.

Commercial Spin-off Companies

These are companies that have been started by the Commercial Space Centers to commercialize research and technologies developed at a Center. Each of these companies represents an effort to commercialize space and leverage the maximum amount of research dollars into the U.S. economy. These companies also ensure the widest possible distribution of the benefits of commercial space and microgravity research to industry and the public.

Agronomy Service Bureau, LLC

was established in 1994 at Kansas City, Missouri to sell a farm-level geographic information system called AgInfo®. AgInfo® was developed by the former Space Remote Sensing Center CCDS, now represented by ProVision Technologies. The Agronomy Service Bureau has a cash investment to date of $4 million.

Applied Optoelectronics Inc.

located at Sugar Land, Texas, was spun off from the Space Vacuum Epitaxy Center in 1997 to market mid-IR LEDs and lasers. Applied Optoelectronics has already broadened its product base to other optoelectronic materials and devices, with a projected 1999 annual revenue of over $1 million.

BioCryst Pharmaceuticals, Inc.

(Nasdaq:BCRX) located in Birmingham, Alabama, is a publicly owned spin-off company of the Center for Macromolecular Crystallography. Working with structure-based drug design, BioCryst is developing a number of treatments for T-cell diseases such as rheumatoid arthritis, psoriasis, HIV, and cutaneous T-cell lymphoma. BioCryst is also developing treatments for cardiovascular disease, with particular emphases on sequelae from cardiopulmonary bypass surgery, and for viral diseases, with a focus on influenza. On September 15, 1998, BioCryst announced that it signed a worldwide license agreement with R.W Johnson Pharmaceutical Research Institute and Ortho McNeil Pharmaceuticals, Inc. (Johnson & Johnson companies) to develop and market products to treat and prevent viral influenza. At the beginning of the fourth quarter, BioCryst's market capitalization was $373 million.

Diversified Scientific, Inc.

located in Birmingham, AL, is a privately held spin-off company of the Center for Macromolecular Crystallography that focuses on diagnostics, software engineering, and optics, with an emphasis on machine vision and imaging for biomedical sciences. Diversified has a cash investment to date in excess of $2 million, and has recently signed an agreement with another company for a minimum of $5 million in sales over the next five years.

Ibbex Pharmaceuticals

located in Birmingham, AL, is a privately held spin-off company of the Center for Macromolecular Crystallography that focuses on developing diagnostics and small pharmaceuticals for the medical treatment of infectious agents using a structure-based, "rational" drug design approach. Ibbex has a cash investment to date in excess of $1 million.

Links Diagnostics

is a company established in 1996 by the former Space Remote Sensing Center CCDS, now represented by ProVision Technologies, to market WHoleView®, a product that uses remote sensing to create a "turf health map" for fairways and greens to help superintendents manage golf courses. Links Diagnostics has a cash investment to date of $1.1 million.

Quantum Devices, Inc.

is a producer of solid state Light Emitting Diodes (LEDs) and miniature optical encoders for use in a variety of commercial applications. It is a privately held spin-off company of the Wisconsin Center for Space Automation and Robotics and is valued at $30 million.

RESOURCE21, Inc., LLC

is developing a constellation of four satellites that will provide crop and vegetation health condition maps to agribusiness every three days. RESOURCE21 was established by by the former Space Remote Sensing Center CCDS, now represented by ProVision Technologies, and has a cash investment to date of $75 million.

Shearwater Polymers

is a privately held spin-off company of the Consortium for Materials Development in Space (CMDS) at the University of Alabama in Huntsville. It focuses on cGMP manufacturing of polyethylene glycol (PEG), and derivatization of therapeutic compounds with PEG to improve drug delivery profiles.

BioServe Space Technologies

By further promoting commercial life science research in orbital space, BioServe Space Technologies enjoyed tremendous success in 1999. Not only did its flight opportunities help advance research in biomedicine, bioprocessing and agriculture, but steps were taken to improve operations and strengthen the support of BioServe's commercial partners.

The results of commercial flight research on STS–95 and STS–93 still are preliminary, but they already are beginning to have an impact on terrestrial operations. Preparations are now underway for a BioServe payload to launch on International Space Station mission 6A next fall.

One of BioServe's leading projects deals with the relationship between gravity and forest products. Lignin is a polymer produced by trees that gives them strength and helps them grow tall. But lignin causes problems in pulping, and processing the lignin results in hazardous environmental byproducts. Reduction of lignin content in trees would provide major economic and environmental benefits to paper and pulp manufacturers. In 1999, BioServe signed a cooperative research and development agreement with the USDA Forest Service Forest Products Lab (Madison, WI) to study the effects of gravitational unloading on commercially used species of trees.

With Amgen Inc., BioServe is studying an osteoporosis medicine—osteoprotegerin (OPG). OPG is a novel bone protein that has potential benefits in treating bone loss. Osteoporosis often is seen as a disease that is only of concern for older women, but this degenerative bone loss affects both males and females of all ages. BioServe and Amgen researchers are working together to evaluate the benefits of OPG treatment under different conditions (such as space flight) to further understand how OPG works and further establish the use of OPG in treating osteoporosis and other bone diseases. A space flight investigation with research animals is being planned for STS–107.

With Bristol-Myers Squibb, BioServe plans to study the effects of space flight on bacterial growth, metabolism and production of secondary products. The information gained from this space research will then be applied towards enhancing drug production in ground-based facilities. BioServe performed additional flight experiments with Bristol-Myers Squibb on STS–95 that validated earlier flight results, but under more optimal processing conditions provided by improved fermentation hardware. In October, Bristol-Myers Squibb agreed to fund ground- and space-based investigations through cash and in-kind contributions, expanding the research into a 5-year program.

Other research projects currently in development include anti-cancer therapeutics, improved resins for use in air and water purifiers, studies on how gravity affects red blood cells, and the production of porous material bone implants.

In FY 99, strategic planning meetings were held with both BioServe offices (CO & KS) in order to improve the organizational structure and overall center operations. This effort resulted in an organizational change, with Louis Stodieck appointed as new Center Director. In addition, two new Associate Directors were appointed, and several hardware engineers and a new marketing coordinator were hired.

BioServe's educational efforts in FY 99 also were highly successful. BioServe increased its K–12 educational outreach effort by supporting a new program called STARS (Space Technology And Research Students) in collaboration with SpaceHab, Inc., a commercial flight carrier. As part of the STARS program, high school students designed and implemented a space research project. The goal of the "Ladybug" project on STS–93 was to observe the effects of space flight on the predator/prey relationship between ladybugs (which hunt "upward" on plant stems) and aphids (which jump "down" to escape).

The STARS program included 6 U.S. schools and one school in Chile, and was supported by a major publishing company to develop and produce a STARS multimedia curriculum. BioServe also held a meeting for a new commercial education initiative called Launch Education into Orbit (LEO) to follow from STARS. In addition, BioServe personnel delivered multiple presentations to schools, organizations and other private groups.

In FY 99, plans were initiated for the Discovery Learning Center (DLC), a new engineering building at the University of Colorado. As part of the DLC, the Space Experiment Institute will promote research as a way to teach students. Students directly funded by BioServe will work in the laboratory, on space flight operations, or with commercial customers.

College students already are indirectly involved with BioServe through work at the Center and through classes taught by BioServe faculty and staff, and directly in laboratory and flight work. Courses include Space Life Sciences, Space Hardware Design, Space Habitation and Habitat Design, Biologically Engineered Control Systems, Biomedical Engineering, Neural Systems, Independent Study and Senior Design laboratory. In FY99, graduates associated with BioServe earned 9 Bachelor's, 7 Master's, and 11 Doctorate degrees.

BioServe initiated a public relations campaign to increase the visibility of commercial research and flight opportunities. This campaign led to BioServe being featured in many newspapers, trade magazines, and on television and radio shows. BioServe's affiliate—Space Age Times, Nutmeg TV of Plainville, Connecticut—featured BioServe's research from STS–95 & 93 on their weekly shows. This educational program promotes public awareness of space research and exploration, and airs from Connecticut to Los Angeles, California.

BioServe supports a NASA collaboration with the National Institutes of Health by providing new commercial hardware to advance important gravitational biology research. In 1999, BioServe's Isothermal Containment Module (ICM) hardware was modified to enable better science with greater precision in support of the NIH investigation on STS–93. The new hardware capability will become the backbone for BioServe's ISS commercial research plans.

In addition, BioServe representatives participated in industry-related conferences, technology transfer forums, and videoconference broadcasts. BioServe also hosted visits with foreign industrial representatives that hold US subsidiaries to expand BioServe's business ventures (e.g., UK Department of Trade and Industry, Brazsat, and Russian District of Agriculture). BioServe is now listed on several online sources (such as Intellectual Property Exchange (IPEX)), and as a result more than 300 industrial contacts have requested information on BioServe's research and flight activities (e.g., Millenium Biologix, Inc., Canada, Wyeth Pharmaceuticals, PA, and Angiotech Pharmaceuticals, Canada).

Case Study

Challenge:

Create a medicine that prevents osteoporosis, a degenerative bone disease.

Importance:

Osteoporosis is a health threat for more than 28 million Americans; it is more common than diabetes, stroke, and heart disease combined. In the U.S. today, 10 million individuals have the disease and 18 million more have low bone mass, placing them at increased risk for osteoporosis.

Solution:

Osteoprotegerin (OPG), a novel bone protein studied by BioServe and Amgen, has indicated significant benefits in treating bone loss.

Benefit:

OPG could reduce the costs of treating fractures caused by osteoporosis and greatly improve the quality of life for millions of older Americans. The current estimated yearly expenditure of hospitals and nursing homes for osteoporosis and associated fractures is $13.8 billion ($38 million each day). Costs are rising; by year 2040 the yearly cost could exceed $50 billion.

Center for Advanced Microgravity Materials Processing (CAMMP)

Ground-based research and preparations for space investigations provided the Center for Advanced Microgravity Materials Processing (CAMMP) with an outstanding year. The research has advanced crucial areas of study and has attracted additional industry interest in the Center, which focuses on understanding how microgravity can be used to improve or enhance materials and their processing on Earth. The hardware development and other preparations are helping ensure that CAMMP and its partners are prepared to obtain the maximum benefit from the opportunities presented by the International Space Station.

In 1999, CAMMP and its Industry Partners focused the majority of research on zeolite and zeo-type materials. These materials form the backbone of the chemical process industry. They are so commercially important to the chemical industry that a number of molecular software companies have been established in order to study the molecular structure of zeolites. An understanding of their molecular structure is vital in order to improve the efficiency of many chemical processes.

However, due to their extremely small size (2 to 8 microns), it is difficult to get accurate structural information about zeolites. Such information can be readily achieved if zeolite crystals 200 to 500 times their normal size can be grown. It is possible to grow such large crystals in the microgravity conditions on the Space Shuttle and the International Space Station.

Once the molecular structure of zeolites is determined, the next step is to control the processes of zeolite nucleation and growth. The ability to selectively process molecules could lead to more energy efficient chemical processes with a significant reduction in undesired byproducts. This could reduce both pollution and production costs. CAMMP plans to target zeolite membranes towards isomerization, dehydrogenation, and desulfurization – reactions that are all critical to the worldwide processing of petroleum and petrochemical products. In addition, novel applications are being developed to use zeolite membranes to separate and purify gases and liquids for pollution control.

Zeolites could also help us move from a petroleum-based to a hydrogen-based economy. Hydrogen would be a highly renewable, pollution-free fuel, because hydrogen is the most abundant element in the universe, and the main product of hydrogen combustion would be H_2O (water). One of the major problems remaining to be solved is the efficient storage of hydrogen, but zeolite and zeo-type materials are one possible storage medium.

Zeolites were not the only area of research for CAMMP in 1999. CAMMP is also working on a method for detection of low-level gases and vapors. Such detection is both an important environmental concern and the first step in monitoring and controlling many chemical and mechanical processes. For example, sensors could control harmful exhaust gases emitted from automobiles by providing a feedback mechanism to adjust the fuel-to-oxygen ratio.

Case Study

Another area of study in 1999 was to explore how gravitational forces alter the kinetics of crystal growth. Gravity-induced changes in a crystal will translate into different photographic behavior. The project, in cooperation with commercial partner Polaroid, intends to link the gravity-altered physical properties of silver halide crystals to their photographically relevant properties. This could someday lead to entirely new types of photographic films.

CAMMP flight hardware has met all requirements for flight on the Space Shuttle and the International Space Station. In 1999, CAMMP hired a computer specialist and design engineer to help with hardware, software, and payload data library activities.

Located in the Egan Research building at Northeastern University in Boston, CAMMP consists of three laboratories: Materials Synthesis, Analytical, and Applications. In 1999, CAMMP was reconfigured for an extra 400 sq. ft. of laboratory space for an air-to-ground communications station. In addition, 1,100 sq. ft. of office space is under construction.

CAMMP is actively pursuing even greater industry involvement. Besides giving presentations at various companies, CAMMP has developed a 7-minute VCR tape and a CD-ROM that highlights CAMMP's activities and capabilities. In addition, CAMMP researchers are collaborating with a number of faculty at Northeastern and other universities on technical research problems and on K–12 education.

CAMMP researchers were very active in 1999, submitting several papers to archival journals, delivering technical presentations, and writing conference procedures. One of CAMMP's undergraduate students took second place in the AICHE Northeast Regional Student paper contest. CAMMP director Dr. Al Sacco, Jr. gave the Distinguished Lindsay Lectureship at Texas A & M, gave 4 key note addresses and 2 high school commencement addresses emphasizing the International Space Station activities. Also, CAMMP researchers gave presentations to general audiences of several professional organizations emphasizing the commercial aspects of NASA's space program. These included a CNN television interview and a 1-hour nationally televised show.

Challenge:

Developing an efficient storage medium for hydrogen fuel.

Importance:

Hydrogen would be a pollution free source of energy. And because hydrogen is the most abundant element in the Universe, the fuel reserves would be virtually infinite.

Solution:

Zeolites and zeo-type materials are being tested as a possible storage medium for hydrogen fuel.

Benefit:

The market for this product would be simply enormous. Hydrogen would replace petrolum, coal, natural gas and other polluting fuel sources. Everything that uses energy—from industrial businesses to farm machines to private homes—would be affected.

Center for Commercial Applications of Combustion in Space (CCACS)

The Center for Commercial Applications of Combustion in Space (CCACS) works with industry to help researchers understand and improve the process of combustion—the most prevalent chemical process and the basis for nearly every major manufacturing procedure. Combustion plays a role in everything from the furnaces in our home to the newest generation of machine tools, and CCACS is helping the combustion industry improve both production and safety.

A new home has just opened up out-of-this-world opportunities for CCACS and its Industry Partners, even if it is just across campus! The 2,000-square-foot facility, along with approximately 8,000 square feet of additional space in academic departments around the Colorado School of Mines campus, will provide ground-based laboratories for research, as well as space for final assembly of hardware for flights on the KC–135 weightless training aircraft, the Shuttle, and the International Space Station. The facility also will provide offices and workspace for the CCACS faculty, staff and students.

One important feature of the new facility is its "Mission Control Center," which will make it possible for investigators to monitor and control investigations on the International Space Station. By using "telescience" capabilities, investigators can more closely control their experiments and take advantage of opportunities as they arise. In addition, this capability will cut down on use of one of the most limited resources on any mission: crew time.

"This facility will offer our Industry Partners the best possible ground-based research, and greatly enhances combined research operations," states Dr. Frank Schowengerdt, Director of the Commercial Space Center. "This will allow us unparalleled opportunities and help advance important research into fire safety, the production of potential bone replacement materials, and development of new processes to make a new generation of machine tools."

Nor was this the only positive move by CCACS this year. Two new Industry Partners joined CCACS: Environmental Engineering Concepts, Inc. and Solar Turbines, Inc. In addition, Chevron Research funded investigations into inorganic membranes, and two hardware elements designed for use on the Shuttle and the International Space Station (ISS) met critical milestones. First, the engineering model of the Water Mist experiment (see Case Study), designed to fly in the Combustion Module aboard the Shuttle and a prototype for use on the ISS, was completed and delivered to the Glenn Research Center for testing. Also, the ISS SpaceDRUMS hardware passed both its Critical Design Review and Phase 0 Safety Review.

Case Study

Investigations were performed on NASA's KC–135 relating to the Water Mist experiment and the Combustion Synthesis of Porous Materials, an investigation that is examining the production of synthetic bone material that can be used to replace human bone damaged by accident or disease. In addition, ground-based investigations were conducted on:

- New or improved ceramics using flame synthesis;
- Catalytic combustion, which holds the promise of greatly increased combustion efficiency with reduced emissions;
- Inorganic membranes, which can help with a variety of chemical operations including separations (refining), catalysts, and sensors;
- The use of water mists in fire suppression;
- Porous materials, which have use as bone replacements, dental implants, high-temperature filters, and catalyst supports;
- High strength diamond cutters, which can be used by the oil industry and all machine tool operations;
- Sensors, which have applications both within the combustion and the medical fields.

Market analyses for the catalytic combustion and porous materials projects were performed by the Colorado Venture Centers, Inc., and showed a very high interest by industry in commercializing and/or licensing the technology in both projects.

In addition, CCACS, along with Industry Partner Guigne International, Ltd., has a patent in process for new processing techniques for glass-ceramics. Fourteen papers were published by CCACS in refereed journals, along with four papers in non-refereed publications. CCACS made eight formal presentations to industry, and students associated with CCACS earned one Master's and five Bachelor's degrees.

1999 has been a moving year for CCACS. From a new research facility, to planning commercial investigations for the International Space Station, CCACS has steadily moved to advance commercial research in space.

Challenge:

With the elimination of halons (bromine-based compounds) for fire fighting, new or improved systems are needed to ensure the safety of our homes, offices, factories, ships, and aircraft.

Importance:

Fires do considerable damage to structures and people each year, and fire suppression is a $2 billion a year industry.

Solution:

Improve the delivery of water so that it is more effective in suppressing fires while minimizing the damage done by the water.

Benefit:

The use of microgravity and the resources of CCACS are allowing Industry Partner Environmental Engineering Concepts to perfect water-based systems that meet the requirements of the Montreal Protocols.

Center for Macromolecular Crystallography (CMC)

With successful commercial investigations on STS–95, and human clinical trials underway by an Industry Partner on a flu treatment, the Center for Macromolecular Crystallography (CMC) has had an outstanding year. But these accomplishments are only a portion of the successes enjoyed by this Center.

CMC has continued to make significant progress in FY 1999 on a wide array of commercially stimulated research and technology developments. The applications of X-ray crystallography for structure-based drug design, combined with combinatorial chemistry and other new computational tools for accelerating lead compound optimization, are providing opportunities for rapidly producing new drugs to treat a number of diseases affecting human populations around the world.

Work primarily has been focused on integrating combinatorial chemistry and calorimetry as added tools to advance structure-based drug design research efforts currently underway within CMC. The Center for Macromolecular Crystallography has entered into a research agreement with ArQule, Inc. to develop drugs against targets using ArQule's compound library. This partnership will offer the opportunity for CMC scientists to begin screening protein targets using ArQule's 45,000 combinatorial library. In addition, Eli Lilly has now contracted work with the CMC because of its unique crystallization (1 g and μ g) capabilities.

A spin-off company, BioCryst Pharmaceuticals, Inc., partnered with R. W. Johnson Pharmaceutical Research Institute and Ortho-McNeil Pharmaceuticals (both Johnson & Johnson companies). Through this agreement, RWJ Pharmaceutical Research Institute and Ortho-McNeil will receive exclusive worldwide rights to develop and market products to treat and prevent viral influenza. The structural information that serves as the basis for this important development was accomplished through a collaborative effort between CMC and BioCryst to determine the structure of influenza neuraminidase. BioCryst and CMC developed four lead orally active product candidates that have potent activity in preclinical trials against both influenza A and B. The Johnson & Johnson companies completed the research and development on the lead compounds and conducted phase I and II human clinical trials.

Work is also underway on two other exciting projects: NAD synthetase and viral influenza hemagglutinin. NAD synthetase is an essential enzyme in all bacteria, and CMC has developed a series of inhibitors that exhibit broad-spectrum antibacterial effects as well as dramatic antifungal effects. The compounds have been shown to be less toxic in whole cell and animal trials than a number of presently approved antibiotic and antifungal compounds. As a result, it is anticipated that a major licensing deal will be made in the coming year. Microgravity-grown crystals of NAD synthetase produced the highest resolution structure of this important enzyme.

Case Study

Viral influenza hemagglutinin is a protein on the surface of the influenza virus that is responsible for viral entry into host cells (neuraminidase is responsible for viral exit from host cells). CMC scientists have developed a series of compounds that bind to hemagglutinin with 100,000 times the affinity of any compound previously reported. It is quite possible that a combination therapy of neuraminidase and hemagglutinin inhibitors will provide the most effective approach for anti-influenza drugs.

In addition to these important product lines, CMC has made progress on a number of flight hardware systems. The X-ray Crystallization Facility (XCF) laboratory prototype was completed in the spring of 1999 and is now being prepared for incorporation into an International Space Station rack. The XCF features a fully robotic crystal preparation system with cryopreservation capabilities. The XCF also includes an X-ray system that uses 24 watts of internal power (as opposed to 6,000 watts for conventional systems), weighs only 60 pounds (as opposed to 1.5 tons for a conventional system), and produces an X-ray beam that is more intense and more parallel than that obtained from the best laboratory systems. Other hardware that has matured during the year include the next generation of incubators, high density protein crystal growth, and a video command and monitoring component that will be incorporated into several pieces of flight hardware.

CMC and its staff have been responsible for more than 45 papers in refereed journals and more than five papers in non-refereed journals, filed for six patents, and made more than 15 formal presentations to industry. One Ph.D. was awarded to a student, and CMC received extensive publicity on and its efforts in both the popular and trade media.

1999 has been an outstanding year for the Center for Macromolecular Crystallography. From advancing commercial product lines, to preparing the hardware and technology needed for future research, significant achievements have been made that are helping pave the way for more successes, and more down-to-Earth products, in the future.

Challenge:

To develop a broad-spectrum antibiotic.

Importance:

Infectious diseases are one of mankind's leading causes of mortality, causing 16.4 million deaths per year.

Solution:

Structure-based drug design, structure-directed combinatorial chemistry, and classical medicinal chemistry technologies have produced lead drug candidates against infectious diseases.

Benefit:

New antibiotics can attack previously unconquered infectious diseases or those that have become resistant to currently available drugs.

Commercial Space Center for Engineering (CSCE)

The Commercial Space Center for Engineering (CSCE) experienced an extremely productive year in 1999. Dedicated to promoting commercial engineering research and technology development on the International Space Station, this newly established Center has identified key industry requirements for commercial activity on ISS and initiated a strategy to satisfy these requirements.

To do this, CSCE collected industry input to define the requirements as well as identify the perceived barriers to ISS commercialization. Once these definitions were in place, CSCE began work to remove real barriers and to educate industry and the government to eliminate misperceptions. A WWW site was established to provide information, and 28 direct technical interchange meetings were held with industry. From the latter, CSCE was able to identify a significant and growing commercial satellite market that can make use of commercial research and development activities on the International Space Station.

CSCE's strategy also includes an approach to promote industry commitment through concept definition studies. These studies, conducted jointly by CSCE and Industry Partners, include an assessment of the business rationale for performing an ISS-based test, a conceptual experiment design, and a cost estimate—information that allows the commercial partner to decide on further investment in actual flight hardware. Three such studies already have been initiated with new Industry Partners and several others are in negotiation:

- Propellant Tank Mass Gauging
  Foster-Miller, Inc.
- Advanced Photovoltaic Array Demonstration
  Tecstar, Inc.
- Spacecraft Heat Pump Demonstration
  Swales, Inc.

In addition, CSCE established an industry support center that includes trained analysts, work stations, and industry standard software. This support center provides CSCE's Industry Partners with professional design capabilities focussed on palletizing engineering payloads for external sites on the International Space Station.

Given that the International Space Station is not yet in orbit, and that CSCE has only been in existence for a little more than a year, these efforts represent a tremendous amount of work and advancement. The foundations being laid by CSCE are helping pave the way for increasingly broad-scale commercial activities involving the International Space Station.

Case Study

Challenge:

Design, build, integrate, and flight qualify a palletized engineering experiment in eleven months to take advantage of a low-cost flight opportunity on STS–107.

Importance:

The successful demonstration of a low-cost star tracker technology (used by satellites to position themselves) via this experiment will simultaneously demonstrate two critical points: (1) space-based, palletized engineering tests have significant utility for developing new commercial hardware for spacecraft, and (2) CSCE has a proven capability to design and build successful space experiments.

Solution:

CSCE staff formed and is currently leading a team, including the Texas A&M Aerospace Department and various industry participants, to accomplish this mission. Key technical requirements and schedule items have been identified, and the team is advancing quickly to the Critical Design Review point.

Benefit:

By pulling out the stops to accomplish this ambitious goal, CSCE will obtain valuable experience and a track record crucial for attracting future Industry Partners. Moreover, a successful experiment will result in a new, commercially available star tracker that can be marketed throughout the spacecraft industry.

Consortium for Materials Development in Space (CMDS)

1999 has proven to be an eventful year for the Consortium for Materials Development in Space (CMDS). As a result of suggestions and recommendations, CMDS has reorganized, obtained a new director, and taken other steps designed to make it even more responsive to the needs of industry.

Dr. William Gathings, the new Director for CMDS, took up his duties on August 30, 1999. Before coming to CMDS, Dr. Gathings was the founding president and scientific director of Southern Biotechnology Associates, Inc., a company with a proven track record in product development and commercialization of technology. Dr. Gathings holds a Ph.D. in immunology from the University of Alabama at Birmingham.

In addition to a new director, CMDS also has established an advisory council to provide direction and guidance to ensure a strong commercial focus. The council will review commercial development plans, perform an annual review of operations, assist with communications between CMDS and its commercial partners, and act as an advocate and ambassador for CMDS. Current members of the council are: James R. Hudson, President of Research Genetics, Inc. (Advisory Council Chair); Milton Harris, President of Shearwater Polymers, Inc.; Tom Dooley, President of IntegriDerm, Inc.; Timothy E. Taylor, Director of Investments for Harbert Management Corporation; Lawrence R. Greenwood, Vice President for Research for the University of Alabama in Huntsville; Steve Lambing, NASA Space Product Development Program; and William Gathings, CMDS Director.

CMDS has streamlined its operations, discontinuing some areas of research while expanding and initiating others. One new effort is an exclusive technology licensing and royalty agreement with Research Genetics, Inc. that covers sets of genes that encode proteins associated with the processes of bone formation and resorption—better known as biomineralization. Another new area of research with Shearwater Polymers, Inc. also involves biomineralization. While formal agreements are not yet signed, discussions are underway for research related to the development of biomineralization proteins that may have utility for treatment of bone and cartilage diseases. CMDS also has completed the preliminary design phase in development of two pieces of spaceflight hardware for the International Space Station.

In 1999, CMDS flew five commercial investigations on the STS–95 mission. The first was an acceleration measurement device payload, under contract from SpaceHab, Inc. for use in evaluating the vibration and microacceleration environment near various payloads in the SpaceHab module. The second was a tissue engineering investigation to examine the development of bone implants/replacements for commercial partner Millenium Biologix, Inc.

The third was an investigation of cell protein products to examine cell aging/death factors for commercial partner Synthecon, Inc. The fourth was an investigation of the production of anti-cancer and anti-alcoholism products from plant cells for commercial partner Hauser Chemical, Inc. The final investigation was a protein crystallization effort on dehydratase, which was conducted as part of a guest investigator program with the Center for Macromolecular Crystallography.

CMDS has been involved in a number of patent issues this year. An internal invention disclosure was signed for a novel technique for growing organic thin films. Notification was received this year that the patent office had ruled against University of Alabama, Huntsville/CMDS on an interference proceeding, regarding a patent filing made by CMDS in 1987 on the first material discovered to be superconducting above the temperature of liquid nitrogen. UAH and CMDS have asked for a review of this finding. A Canadian patent was issued in 1998 for "High temperature processing of cuprate oxide superconductors." In addition, a 1997 filing for a patent on "Modified brushite surface coating process therefore, and low temperature conversion to hydroxapatite" still is under review.

CMDS also has seven papers published or in press with refereed journals, and has presented 26 other papers or presentations to non-refereed journals or conferences. In addition, a book contribution was made by CMDS researchers to *Recent Developments in Crystal Growth Research*, published by Transworld Research Network. Four formal presentations were made to industry as well.

Students employed by CMDS earned one B.S. degree, two M.S. degrees and one Ph.D. The graduate degrees resulted in theses on "Purification and closed tube vapor growth of mercurous chloride single crystals," "Microstructure evolution of liquid phase sintered Co-Cu samples in microgravity," and a dissertation on "Grain growth kinetics modeling in microgravity liquid phase sintering."

While 1999 has been a difficult year for CMDS in some respects, it has also been a year of advancement. The introduction of a new director and the addition of new commercial partners will ensure the continuing development of CMDS and its commercial research.

Case Study

Challenge:

Develop a microarray for evaluating the genes that encode proteins associated with biomineralization, the process by which bones and cartilage are formed or reabsorbed by the body.

Importance:

The use of high density gene array technology for analysis of gene expression before, during and after prolonged exposure to microgravity will be valuable in the discovery of strategies to combat these harmful effects. This technology could also improve methods for treatment of diseases with similar phenotypes prevalent on Earth, such as osteoporosis.

Solution:

CMDS facilitated the establishment of research collaborations between Research Genetics, the commercial partner, University of Alabama, Huntsville's Laboratory of Structural Biology, and experts in the field of biomineralization. This collaboration has provided cutting edge technical information, as well as research materials (e.g., bone cell lines) that are essential to the gene discovery process.

Benefit:

By working with CMDS, Research Genetics has ready access not only to a state-of-the-art gene discovery, protein expression and protein purification facility, but also to skilled professional and technical personnel, enabling Research Genetics to shorten product development time.

Medical Informatics & Technology Applications Consortium (MITAC)

The Medical Informatics & Technology Applications Consortium (MITAC) continued its efforts to develop out-of-this-world medical products during 1999. MITAC explores new technologies in medical informatics and health care delivery systems that could revolutionize health care in space and on Earth. The prime focus of MITAC is on evaluating and preparing products and processes—such as telemedicine—for human space flight.

Originally established at Yale University School of Medicine in 1997, MITAC was relocated to Virginia Commonwealth University (VCU) on July 1, 1999, and is now located on VCU's Medical College of Virginia campus. Interactions with NASA Headquarters and field centers such as Ames Research Center, and Johnson Space Center have resulted in a concentration on space flight and technological commercial applications.

By studying extreme or remote environments, such as Mt. Everest or the jungles of Ecuador, MITAC is working to gain an understanding of the cultural differences in health care throughout the world. This will help MITAC develop and advance telemedicine—where doctors don't need to leave their office in order to examine patients on the other side of the world.

MITAC's efforts were almost literally on top of the world earlier this year, when the Everest Extreme Expedition '99 (E^3) team used the technology to help ensure the health of its participants. Medical personnel with the expedition shared visual representations, ultrasound images, blood chemistry, and other important medical data with experts worldwide (at any facility with Internet-based videoconferencing capability). The technology also allowed for real-time monitoring of the climbers as they scaled the world's highest mountain, thus providing a supervising capability that enhanced climber safety.

"A key component of this demonstration was the ability to monitor the climber's physiology and location during the climb," states Charles R. Doarn, Executive Director of MITAC. "The kinds of activities with which MITAC is involved will enhance healthcare capabilities on Earth and on space flights, with the International Space Station and on more advanced missions and operations."

Similar activities have been conducted in Ecuador through Operation Rainforest. Using telemedicine and telementoring, physicians in the U.S. and Ecuador can collaborate on unique surgical intervention between a remote, mobile surgical vehicle and a fixed facility.

MITAC published a number of manuscripts in refereed journals in 1999, and held a number of informal meetings with industry. MITAC also established a Board of Directors comprised of members from industry, academia and other government agencies.

Case Study

Challenge:

Develop a telemedicine system that includes the ability to monitor a climber's location and physiology during an attempt to climb Mt. Everest.

Importance:

Such a system not only benefits the climbers, but helps advance technology needed for advanced space medicine applications.

Solution:

MITAC worked with industry to develop the necessary hardware to make the telemedicine system possible.

Benefit:

Everest climbers benefited from advanced medical care, paving the way for advanced telemedical care for astronauts during spaceflight.

ProVision Technologies (PVT)

ProVision Technologies experienced a great year, thanks to its Hyperspectral Imaging System. This system can be used to improve the health and safety of both people and the environment by reading emissions of electromagnetic energy unseen by the human eye. The Hyperspectral Imaging System can help us learn more about the human body than ever before, and improve life both on Earth and in space.

The Hyperspectral Imaging System is a lightweight, portable instrument that captures electromagnetic energy in the 400 to 900 nanometer range. The HyperVisual Image Analyzer® is a user-friendly software package that will be provided with ProVision's patent-pending Hyperspectral Imaging System. The software is used to capture hyperspectral data, view and calibrate raw data, remove inherent noise, save various data types, and provide speed intensive processing.

The Hyperspectral Imaging System is a single sensor with multiple purposes. For example, on the International Space Station, the sensor could be used to monitor crew health, map an environmental hazard on Earth through a window, or be placed on a robotic arm to monitor the Space Station's environmental and structural health. On Earth, the sensor could detect contaminants in food headed for the grocery store. The sensor could also be used to scan patients for the early detection of cancer.

In 1999, ProVision Technologies created a website (www.pvtech.org) and placed public-relations spots in trade journals in an effort to encourage commercial participation in hyperspectral imaging. ProVision sifted through the overwhelming industrial response to create a solid database of 56 industry contacts interested in developing a relationship with ProVision. The breast cancer research conducted this year, for instance, was a direct result of this successful outreach effort.

The applications for hyperspectral imaging seem to be virtually unlimited. Market sectors addressed this year were skin and breast cancer, wounds, skin health and cosmetics, food safety, and plant traits.

As a non-invasive medical technique, the Hyperspectral Imaging System is making strides toward the non-surgical diagnosis of cancer. The sensor could be used for the early detection of skin cancer, for instance, by scanning a person's skin for the spectral signature of cancer. ProVision personnel and the Hypersectral Imaging System visited the Medical College of Wisconsin in 1999, capturing images of patients who suffered from diabetic ulcers or cancer. ProVision also traveled to Hartford, Connecticut to see if the lymphatic system could be mapped using hyperspectral imaging. Hyperspectral imaging potentially also could be used to diagnose suspected cancerous lymph nodes and malignant tumors during cancer surgery.

Hundreds of thousands of wounds, burns and lesions are reported in the United States annually. Spectral analysis could be used for monitoring the wound healing process. This type of monitoring may provide information that suggests the application of a specific medication or procedure to help accelerate the healing process. This technique could also help astronauts, because wounds or cuts incurred in space do not heal properly.

In 1999, ProVision brought its Hyperspectral Imaging System to Estee Lauder's Research Park on Long Island, New York and captured over 500 images of human faces and forearms. Initial results indicate that various age groups, skin types and age spots

possess different spectral characteristics. This suggests that cosmetic products could be designed around the specific spectral characteristics of an individual's skin.

Sanderson Farms, a large chicken processing company in the southeastern United States, and the U.S. Department of Agriculture are ProVision's partners in developing hyperspectral imaging tools for improving the safety and quality of food products. In 1999, the group focused on detecting contaminated chickens during commercial processing. Sanderson Farms provided all the birds that were imaged by ProVision to determine the spectral patterns of feces, tumors, lesions and bruises. The next objective is to further define the spectral pattern differences between contaminated and wholesome chickens, using the Hyperspectral Imaging System on the chicken processing line.

Monsanto, Walt Disney's Epcot Center and Dynamic Corporation are working with ProVision to determine plant characteristics through hyperspectral imaging. The sensor can detect, for instance, differences in copper levels between plants that appear to be physically identical. This type of detection technique could help in determining environmental problems caused by both natural and man-made toxic conditions. ProVision and Dynamic Corp. are applying spectral analysis to a toxic plant study at The Land at Epcot, which can be viewed from the boat tour through the greenhouse. Hyperspectral imaging also has potential in biotechnology research; Monsanto's new Round-Up Ready Soybeans are immune to the herbicide Round-Up, allowing farmers who spray their Monsanto soybean crops with that herbicide to kill only the weeds. These new, genetically-altered soybeans are currently undergoing spectral analysis to determine exactly how they differ from normal soybeans.

ProVision hopes to eventually spin-off the Hyperspectral Imaging System into another company. "Having the machine is one thing," says ProVision Director George May. "Making sense of all the information is something else."

In the future, ProVision is looking to develop other sensors capable of reading more areas of the electromagnetic spectrum, such as ultra-violet (UV), mid-Infrared, and thermal.

Case Study

Challenge:

Design an imaging system to detect contaminated chickens in a processing plant, where chickens are processed on a line at a rate of 70 to 140 chickens per minute.

Importance:

The United States per capita consumption of chicken meat is 81 pounds and over 8 billion chickens are processed each year.

Solution:

Chicken tumors, tears, bruises, and feces have spectral properties that are different from healthy chicken skin and can be detected using hyperspectral imaging.

Benefit:

Improved safety and quality of chicken meat for the American consumer.

Solidification Design Center (SDC)

The Solidification Design Center (SDC) has had a successful year. A bold new strategy for business involvement is already paying dividends, while ongoing research is helping prepare for commercial investigations on the International Space Station.

While metal casting is a $25 billion-a-year industry in North America, the majority of the approximately 3,000 casting plants in the United States are small, owner-operated businesses with minimal financial resources for individually financed research and development. In fact, 80 percent of all foundries have fewer than 100 employees, and only 6 percent have more than 250 employees. Individual research initiatives within these companies tend to focus on evolutionary, rather than revolutionary, improvements to operations. For this reason, the American Foundrymen's Society—the primary professional organization for the industry—actively has pursued a strategy of coordinating research and development efforts across the industry. This coordination allows investments to be financially leveraged and targeted for maximum impact for the overall benefit of the industry, its customers, and society at large.

Since it is not feasible for the majority of small companies to fund individual research efforts through the Solidification Design Center, a special partnership has been established with the American Foundrymen's Society to develop, fund, and direct industry-reviewed research that will benefit it members. This unique and innovative collaborative arrangement allows industry-wide projects to be continuously monitored by a dedicated team of industry volunteers. In this way, the entire industry becomes involved and benefits from the research.

This collaboration also sets the stage for future, wide-scale proprietary research by individual companies, as the value of space and microgravity-based research is made clear.

In the first round of reviewed industry research, nine proposals were submitted to the partnership, with four being selected. Those four are:

Microgravity Experiments for Enhancing the Development of Ferrous Metals Castings. The commercial affiliate for this project is Professional Metallurgical Services.

An Investigation of the Influence of Convection Induced by Buoyancy and Marangoni Forces on the Hot Tearing of Light Metal Alloys Used in Aerospace Applications. The commercial affiliates for this project are Queens University, CANMET, and Allied Signal.

Development of Computational Fluid Dynamics Software to Support Optimization of Sand Core Blowing Operations. The commercial affiliates for this project are Flow Simulation Services and GM Powertrain Group.

Virtual and Physical Simulation of Metal Casting on Earth and in Space. The commercial affiliate for this project is K+P Agile, Inc.

Research has begun on these efforts, and further work is underway with the American Foundrymen's Society. Industry, space commercialization, and the Nation will all benefit from this cooperative arrangement.

This innovative program has not limited individual industry partnerships in any way. Research efforts are also underway with individual Industry Partners including the ALCOA Technical Center, Anter Coporation, Citation Corporation, Howmet Corporation, PCC Airfoils, Inc., and United Technologies Research Center.

In addition to these efforts, SDC and its personnel have four patents in process, produced five publications for refereed journals and four articles for non-refereed publications. Twenty students involved with SDC earned Bachelor's degrees, and one earned a Ph.D.

Case Study

Challenge:

The U.S. manufacturing industry is under increasing pressure to produce higher value products at lower costs and with minimal environmental impact.

Importance:

The U.S. metalcasting industry ($25B annual sales) is a major supplier to the U.S. manufacturing industry, which comprises 20% of the economy.

Solution:

Improve the ability of design engineers to utilize advanced metal castings in complex assemblies to reduce overall life-cycle costs.

Benefit:

The use of microgravity and the resources of SDC are allowing industry affiliates like Citation Corp. and GM Powertrain Division to perfect innovative casting designs and processes to satisfy the cost, quality, and schedule requirements of their customers.

Space Vacuum Epitaxy Center (SVEC)

The Space Vacuum Epitaxy Center (SVEC) has spent a busy year researching advanced thin film materials and devices for commercial applications. These thin film projects covered everything from fuel cells for the ubiquitous laptop computer to a revolutionary bionic eye that could help restore sight. These thin films are created using vacuum growth technologies developed for space flight.

SVEC is currently organized into research & development projects on nitrides, optoelectrics, advanced oxides, and photovoltaics.

Nitride materials and devices can be used for environmental control and monitoring. In addition, nitrides have applications in high power, high temperature industrial processes. SVEC is specifically targeting biohazards and semiconductor processing for nitride thin film applications. For instance, through a collaboration with NASA's Johnson Space Center, nitride materials will be tested to see how well they operate as a sensor for monitoring water contaminants.

SVEC and a spin-off company, Applied Optoelectronics, Inc, have developed unique semiconductor InfraRed (IR) lasers. The lasers can be used in environmental monitoring, medical therapy, and for defense. With NASA's Jet Propulsion Laboratory, Boston University, and the University of California, Los Angeles, SVEC is developing a compact, high power, multi-spectral laser for chemical sensing. The IR lasers can also be used in medical procedures that use light to activate drugs.

A cooperative biotechnology program between SVEC, the University of Texas Health Science Center, Baush & Lomb, and Alcon, Inc. has made possible the development of a bionic eye—oxide materials and devices are used to create ceramic microdetectors that can be directly implanted into retinally-diseased eyes in order to restore sight. Thin film oxides also have use in both civilian and military 'night vision' technologies. Oxide films are used for superconductors and in machines like the laptop computer. Oxides also can be used in environmental monitoring devices: a linear 24-pixel detector design is currently being tested as an oil-on-water sensor.

Currently, photovoltaics need greater solar cell efficiency in order to make solar energy a viable energy alternative. A partnership between SVEC, the Center for Space Power, and the Commercial Space Center for Engineering is developing a SVEC-patented multi-junction, multi-quantum well solar cell technology to improve solar cell efficiency. SVEC has developed a metal-organic molecular beam epitaxy method to grow the entire solar cell device in a short amount of time, with fewer adverse effects and improved yield. This process could lead to less toxic waste and lower production costs for thin film solar cells. SVEC is currently negotiating an integration plan with Riber, Inc., the world's leading manufacturer of molecular beam epitaxy production machines.

Case Study

With Astropower, Inc., thermophotovoltaic materials—which convert heat (thermo), rather than light (photo), into electricity—also are being investigated as an alternative energy source.

SVEC conducted three market studies in 1999 in cooperation with the University of Houston's College of Business Administration. One study identified a large market for newly developed thin film oxide fuel cells that significantly extend the operation time of laptop computers. Two other studies identified the most appropriate target markets for certain environmental chemical sensors and ceramic capacitors, and initiated technical information exchanges with potentially interested companies.

News media coverage of 1999 activities included the Houston Chronicle and The Christian Science Monitor, as well as many local radio and television stations. SVEC researchers published 49 papers in professional trade journals, and gave 23 presentations to industry.

Challenge:

Restoring sight to people whose retinas have been damaged or are diseased.

Importance:

Not only could such technology restore people's sight, but it could also improve our understanding of how the brain and the eyes interact.

Solution:

SVEC, the University of Texas, and Bausch & Lomb and Alcon, Inc. together developed ceramic microdetectors, or a "bionic eye," that can be surgically implanted for the restoration of vision.

Benefit:

This implant could allow thousands of people to once again see the light.

Wisconsin Center for Space Automation and Robotics (WCSAR)

Two extremely successful commercial payloads were the capstone to an outstanding year for the Wisconsin Center for Space Automation and Robotics (WCSAR). These payloads not only met the goals set for them by industry, they also offer intriguing possibilities for future commercial exploration.

The Space Rose investigation, sponsored by WCSAR's Industry Partner International Flavors and Fragrances, Inc. (IFF), was a unique commercial payload. The miniature rose in its growth chamber captured the eye and imagination of both the broadcast networks and international print publications. The rose was flown to see if the microgravity environment would alter the fragrance of the rose—something very important to the multi-billion dollar-a-year flavors and fragrance industry. Instead of the alteration, however, researchers were presented with an entirely new scent from the rose.

"The fact that fragrance molecules do change in proportion to one another promises to lend a greater dimension to future fragrance research and the possibility of using microgravity to create new fragrance entities, or, for that matter, any chemical products including possibly pharmaceuticals, that the plant produces," states Eugene Grisanti, Chairman and CEO of IFF. Dr. Braja Mookherjee, Vice President of Global Natural Products Research states "This transformation has created a completely new fragrance that is not of this Earth. IFF intends to further explore space research on living plant materials to benefit mankind."

Any gambler will tell you that odds of 1 in a 1,000 or worse is not a good bet. Yet those are the odds facing researchers trying to transfer desirable genes into food and other important crops. A gene transfer was conducted on STS–95 to investigate the impact of microgravity upon the efficiency of the gene transformation protocol applied to the soybeans using an agrobacterium technique. In this investigation, WCSAR and its commercial partners, Rapigen LLC, The Indiana Crop Improvement Association, Inc., and the University of Toledo, transferred the commercial genes into 1,000 soybean seeds in a ASTROCULTURE™ Glove Box payload. The experiment consisted of a number of bags filled with seeds and syringes holding fluid solutions that contained desired genetic traits. The fluids were mixed with the seeds at specified times, and the reaction modified the seed's genetic structure.

"The level of genetic transfer was way beyond our expectations," says Ray Bula, a Principal with Rapigen LLC and a retired director of WCSAR. "We thought that if we could double the rate of transfer seen on Earth, it would have been promising." According to Bula, instead of simply merely doubling genetic transfer rates, there was more than a 10-fold increase compared with the ground-based control experiment. The protocol used in STS–95 experiment has been modified by WCSAR to further improve the transformation efficiency and stability. This modified protocol will be used in the second commercial gene-transfer experiment to be conducted on STS–101 mission.

In addition to these two successful payloads, WCSAR has experienced many other positive advances this year. Dr. Weijia Zhou has been named as the new WCSAR director, and brings his extensive program management skills to the position.

Commercialization efforts continue, with agreements being signed with Fisher Science Education, Producers' Natural Processing Corporation, Space Explorers Incorporated, Automated Agriculture Associates, Orbital Technologies Corporation, and American AgTec International Limited. Each of these agreements is helping advance space-based research, improve ground-based applications and operations, and establish a revenue stream for the different areas of research and development.

Extensive publicity was received by WCSAR as a result of the two STS–95 investigations, with more than 60 print articles published worldwide and extensive coverage provided on national television. WCSAR also had four articles published in refereed publications and three articles in non-refereed outlets, and WCSAR representatives made seven formal presentations to industry. Two Bachelor's degrees and two Master's degrees were awarded to four of the ten students working at WCSAR during FY 1999.

Case Study

Challenge:

Determine if microgravity alters the production of essential oils in plants.

Importance:

Essential oils provide plants and foods with flavor and fragrance, and even minor changes in their composition can open up many new areas for the multi-billion dollar-a-year flavors and fragrances industry.

Solution:

WCSAR modified its commercially available commercial plant growth chamber to fly a rose on STS–95 and take samples using proprietary hardware from Industry Partner International Flavors and Fragrances.

Benefit:

WCSAR's hardware allowed the research to develop rapidly and inexpensively, and opened a new frontier in flavors and fragrances.

Industry Partners

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- AeroChem Research Laboratories
- Aeroponics International, Incorporated
- AgrEvo USA
- Airsys ATM
- ALCOA
- Allied Signal, Incorporated
- American Ag-Tec International Limited
- American Foundrymen's Society
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- WTC/PentaPure Corporation

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