Report on the Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) Programs at NASA




SBIR/STTR

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CONTENTS

MESSAGE FROM THE PROGRAM EXECUTIVE

With the arrival of the new millennium, NASA continues to lead the way with creative opportunities through the Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs to develop the technologies that our parents and grandparents could only dream about. Across the Nation, small high-technology firms are performing research and development in support of NASA goals to maintain the leadership of the United States in Earth and space science research, aerospace development, and space exploration. At the same time, these companies are helping to maintain a strong technology development base in the U.S. economy.

In this report you will find NASA SBIR and STTR success stories to inspire and encourage a new generation of innovators who will lead our Nation through the next century, including

- A technology derived from NASA Space Shuttle plant growth experiments that led to the development of pinhead-sized light-emitting diodes (LED's) with potential for cancer treatment applications.

- Multiple cutting-edge aircraft technologies brought to a single focus with the purpose of supporting the development and manufacture of a new class of aircraft that will revolutionize the general aviation industry.

- Robotic technology that is on its way to making beating heart bypass surgery a reality.

These stories illustrate clearly that the SBIR and STTR programs address some of the most difficult challenges and yield significant technologies that can have a far reaching impact on the economy.

The NASA SBIR and STTR programs target three strategic objectives for program success: the cultivation and development of innovative solutions, the nurturing of partnership agreements, and the facilitation of commercial opportunity. This report will show how the programs not only contribute to the reduction of taxpayer dollars required to carry out NASA missions, but also create excitement—both inside and outside of the Agency —about the strides being made in technology.

The SBIR and STTR programs provide an avenue for small businesses to meet many of NASA's research and development needs. NASA views the cadre of small businesses, including woman- and minority-owned businesses, as a vital link to our future as an Agency. The innovative, bold, aggressive approaches of these companies to research represent the best in NASA's spirit of doing business better, cheaper, and faster.

Some of the changes to the programs that are given in this report, such as the alignment of topics and subtopics to NASA mission and program goals and the implementation of a totally electronic management and submission system, are evidence of a renewed spirit in the NASA SBIR and STTR programs. That spirit, growing across the Agency, is all about "helping small business make a big difference."

Carl G. Ray
Program Executive

NASA continues to lead the way with creative opportunities through the Small Business Innovation Research and Small Business Technology Transfer programs to develop the technologies that our parents and grandparents could only dream about.

Both the SBIR and STTR programs are designed to allow small businesses and research institutions to participate in the Nation's annual multibillion dollar investment in research and development. The programs fund projects that lead to new technologies that have high commercial potential and consequently advance U.S. economic productivity and international market competitiveness.

This report details the new NASA SBIR and STTR programs. There are statistics on program participation, status of strategic initiatives, and an extensive look at program results over SBIR's 16-year history. But most importantly, success stories about individual SBIR projects and aspects of technical and commercial accomplishments are described. We are all very excited about the current momentum of the programs and with feedback from this report we hope to make further refinements. NASA SBIR and STTR programs are "programs that can and do deliver."

Carl G. Ray
Program Executive

PROGRAM MANAGEMENT

The Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs provide a significant opportunity for NASA to benefit from the innovations of small high-technology U.S. firms and research institutions. SBIR and STTR contractors perform basic research and development (R&D) in three competitive phases that can benefit future missions of the Agency. The first phase is essentially a feasibility study; it is a 6-month contract for up to $70,000. The second phase is more substantial and is where most of the development work is done. The phase II contract is for up to 24 months and $600,000. The third phase provides a wonderful opportunity for small U.S. businesses to leverage their government funded R&D into commercial products that benefit the economy of the Nation.

Ten federal agencies have SBIR programs, with total federal funding in excess of $1 billion annually. The program now provides the largest source of preventure capital within the federal government. Governmentwide, over 11,000 companies have received funding through the SBIR program since 1983; more than 250 former SBIR firms are now publicly traded.

Within the Agency, these programs also represent the largest interface with for-profit firms. As a result of the 2000 SBIR solicitation, NASA received 1,847 proposals from 771 companies in 47 states. From these proposals, 288 phase I awards were made to 210 firms in 37 states. The combined SBIR and STTR programs awarded 437 new contracts in fiscal year 2000, which is approximately 50 percent of new research and development contracts awarded by the Agency.

Over the past several years, the NASA SBIR management team has consistently emphasized four basic principles for the administration of the NASA SBIR and STTR programs. These principles are

1. Alignment of research topics to the highest technology priorities of the Agency.
2. Focus on program effectiveness as measured by phase III commercialization.
3. Enhance program efficiency by using advanced information technology.
4. Provide opportunity for a cross section of small U.S. businesses.

Alignment of Research Topics to Agency Technology Priorities

The SBIR and STTR programs are fully supportive of the technology needs and priorities of the Agency. The NASA Strategic Plan, the Enterprise Strategic Plans, and the Center Strategic Implementation Plans are the guiding documents for achieving this goal. Based on these documents, and with significant involvement from the NASA Strategic Enterprises, we seek small businesses to participate in the R&D of critical technologies that enable future missions.

Beginning in 1997, the SBIR program aligned its annual solicitation by Strategic Enterprise. Each Strategic Enterprise Associate Administrator designated a representative to work with the SBIR program. The representative communicates the technology

"The NASA SBIR program has given Scientific Materials Corp. the opportunity to make its concepts for improved optoelectronic materials a reality. These materials led to the development of new lasers and other devices for broad base commercial applications in remote sensing, medical, and lithography technology."

Ralph Hutcheson
President, Scientific Materials Corp.

"These technologies would not have been commercially feasible without the support of the SBIR program. The follow-on commercial support that was built directly on this early research has enabled the company to grow substantially."

Kevin Burns
Precision
Combustion, Inc.

planning activities of the Enterprise to the SBIR management team at the Centers, as well as integrates the SBIR program into the technology planning activity of the Enterprise. Significant efforts in communication and integration have resulted in the annual solicitations that reflect the Agency's technology taxonomy.

The STTR program focuses on early technology development by requiring a research institution (typically a university) to cooperate with a small business to submit proposals. This program supports NASA's core competencies as defined in the Strategic Plan. Beginning with the 1999 solicitation, the STTR program was aligned with the Agency Centers of Excellence. Because of the limited budget, each Center of Excellence participates in this program every other year.

Program Effectiveness as Measured by Phase III Commercialization

A key congressional intention of these programs is to assist small, high-technology U.S. businesses to fund their early R&D efforts and move the resulting technologies into commercialization or phase III of the program. For the SBIR and STTR programs, phase III commercialization is defined as either (1) further development and use of the technology in a federally funded effort or (2) development of the technology for sale in the commercial marketplace. NASA SBIR and STTR programs seek to fulfill both of these congressional intentions.

Infusion of successful SBIR developed technologies into NASA missions is critical to the success of these programs and is an aspect of the program that is increasingly emphasized. Correlation of solicitation topics to Strategic Enterprise mission needs is resulting in a substantial increase in phase III contracts. In fiscal year 2000, 23 new phase III contracts were issued with a total value of $90.4 million.

At the end of December 2000, the NASA SBIR program has documented 348 commercial success stories. These stories are published on the Internet at http://sbir.nasa.gov.

Enhancing Program Efficiency through Information Technology

The third management principle guiding these programs is the use of advanced information technology to operate the programs more efficiently.

This goal was realized with the development and use of innovative Internet-based electronic handbooks (EHB's). EHB's were originally funded by the NASA SBIR program at Goddard to manage complex distributed information processes in an integrated and intuitive environment. The successful implementation and deployment of EHB's led to a phase III award in August 1998. The objective of this continuing effort is an end-to-end, Internet-based, paperless system supporting all SBIR and STTR management processes.

EHB's are a cost-effective and efficient means of reengineering and modeling business processes. The EHB's guide the user through the necessary forms and menus to execute the defined processes. The EHB's have the end-to-end management process flow, which includes solicitation development, proposal submission, proposal evaluation and selection, contract negotiation, and contract

reporting. Benefits of EHB's include greater data accuracy and quality, faster turnaround time, increased synergy, imbedded e-mail features for effective communications, and rapid acceptance by a diverse user community. The real-time online information in the EHB's facilitates comprehensive reporting, analysis, and decision making. This technology is now being transferred to other NASA program management offices such as the Earth Science Technology Office (ESTO) at Goddard Space Flight Center (GSFC) and other federal agencies (e.g., Department of Justice Bulletproof Vest Program). The EHB's have been recognized in articles published in the *Washington Post*, *Government Executive*, *NASA Tech Briefs*, and *Federal Computer Week*. The EHB contractor, REI Systems, Inc. has been awarded the Small Business Administration's Administrator's Excellence award (June 1999); a NASA Space Act Award ($10,000); and the Small Business Administration's Tibbett's Award.

Opportunities for Wide Array of Small U.S. Businesses

The fourth management principle is to provide an opportunity for a cross section of U.S. businesses to participate in the NASA SBIR and STTR programs. We do this by broad dissemination of program information on the Internet at http://sbir.nasa.gov and by reaching out at numerous regional and national SBIR conferences. Consistent with the congressional intent of these programs, we specifically reach out to underrepresented groups.

In recent years, over 25 percent of NASA's SBIR awards were made to firms owned by minorities or by women. While this is not a selection criteria, we are proud of the fact that these percentages have increased in recent years and indicate a high level of diversity (and opportunity) within the program.

There is also a large technological, as well as geographical dispersion within these programs. This year, the SBIR program will include 108 separate technology areas that support all five NASA Strategic Enterprises and will be administered at all ten NASA field installations. Since the program's inception, contract awards have been made in all 50 states to approximately 2,000 small business concerns.

SBIR and STTR Future Objectives

These programs are critical sources of new technologies that enable future NASA missions. The processes, incentives, and information exchange pathways necessary for NASA to benefit from SBIR and STTR technologies are being developed not only for specific customers, but also for a broad array of NASA missions.

To be truly successful, we must bring potential NASA customers into the technology identification, development, and infusion process. The continued development of electronic tools for rapid transfer of innovative technologies into mission applications will help us reach this goal.

W. Paul Mexcur
Program Manager

There is also a large technological, as well as geographical, dispersion within these programs.

EXCERPT FROM NASA SBIR COMMERCIAL METRICS REPORT

In accordance with the Government Performance and Results Act (GPRA) of 1993, NASA is required to demonstrate that its programs contribute to the Nation's economic well-being. One of the elements of that effort is a commercial metrics survey protocol that NASA designed and implemented to try to quantify the commercial activity associated with its Small Business Innovative Research (SBIR) program.

While the primary purpose of NASA's SBIR program is to meet NASA mission-related technology needs, commercial application of NASA-funded SBIR technology is a strong secondary objective and is an imperative under GPRA as well as NASA's Strategic Plan. Accordingly, the NASA SBIR Solicitation emphasizes the importance of commercial potential of NASA-funded SBIR technology.

NASA's SBIR commercial metrics survey provides a mechanism to identify not only the commercial applications of NASA SBIR technology, but also other measures of commercial activity. The survey is designed to capture data on sales of products and/or services, as well as to reveal commercial intent. For example, cases where the firm has taken significant steps toward a commercial venture at least partially based on NASA SBIR technology, but a resulting product or service has not yet been (or perhaps never will be) sold are measured by the survey.

Submission of a completed survey form reflecting efforts to commercially apply technology gives the respondent an excellent opportunity to show commercial intent and commercial capability with respect to NASA SBIR developed technology. Specifically, submitting the survey form lets NASA give credit for commercial information that might not otherwise be included in the information on commercialization potential typically provided in proposals. Firms completing the survey are eligible to submit their technologies for publications in the *NASA Tech Briefs* magazine at no cost. *NASA Tech Briefs* has a readership of over a half million individuals per month.

The universe of firms having received NASA phase II awards over the 1983 to 1994 period is 723 companies. Currently, about 75 percent of the firms have responded, 8 percent have not responded, and NASA has been unable to locate the remaining 17 percent. Of the firms we could find, about 91 percent have responded; they represent over 80 percent of the 1,443 phase II contracts awarded by NASA over the 1983 to 1994 period.

Survey results show that over 30 percent of NASA phase II awards have produced technology that has been incorporated into revenue generating commercial products and services in nongovernment markets. More than 450 associated commercial products and services in numerous industrial sectors are represented. This demonstrates the pervasive effect of NASA's SBIR program on the national economy.

The survey results also show significant commercial intent to apply NASA-sponsored SBIR technology in nongovernment markets. Specifically, for more than 35 percent of phase II's awarded by

NASA over the 1983 to 1994 period, the technology was either incorporated in products and services generating revenues in non-government markets or the firm took significant action to develop a commercial venture at least partially based on the technology. The survey also shows that the degree of strategic alliance partnering among SBIR and non-SBIR firms regarding ventures producing these products and services is significant.

Among other findings, the survey shows that about 90 percent of all firms winning NASA phase II awards have previously received three or fewer NASA phase II awards. Over the past five years, about 46 percent of all firms receiving NASA phase II awards for that period are new to NASA's SBIR program. This particular finding shows that there is significant opportunity for newcomer firms to enter the program.

NASA has extended its survey universe to include all of the more than 800 firms having received NASA SBIR phase II awards over the 1983 to 1995 SBIR award year period. Results are being compiled. The Office of Management and Budget has reauthorized both the survey instrument and methodology for another three years.

Copies of NASA's SBIR commercial metrics survey form may be downloaded from the NASA SBIR web site at http://sbir.nasa.gov. Firms should return completed survey forms to Jack Yadvish, Code RW, NASA Headquarters, Washington, DC 20546. Firms generally will not be requested to update the survey information more frequently than about once every two to three years, voluntary updates are invited at any time. Any questions regarding completion of the two-page form should be referred to Mr. Yadvish at 202-358-1981.

NASA Utilization of SBIR-Developed Technologies

A primary objective of the NASA SBIR program is that the work benefits the Agency. The SBIR Program Office is continually looking for ways to better bring those benefits to NASA. The realignment of the solicitation to reflect the needs of the Enterprises is one example; our increased emphasis of publicizing successes is another. Further, the SBIR and STTR programs are increasingly viewed as an important leveraging tool for the development of technologies, and their applications, needed for NASA mission success.

Many of the successful SBIR and STTR technologies that have been incorporated into NASA spacecraft and instruments did not get there as part of any preconceived plan to utilize the SBIR program to solve a mission need. Frequently, it has been the persistence of both the small business and the NASA personnel that has led to the technologies being used by missions.

In recent years, some NASA programs have taken a strategic approach to using the SBIR and STTR programs to help achieve goals and objectives. The success of this strategic approach, especially technologies relevant to General Aviation, has influenced other NASA programs toward including the SBIR program in their planning processes.

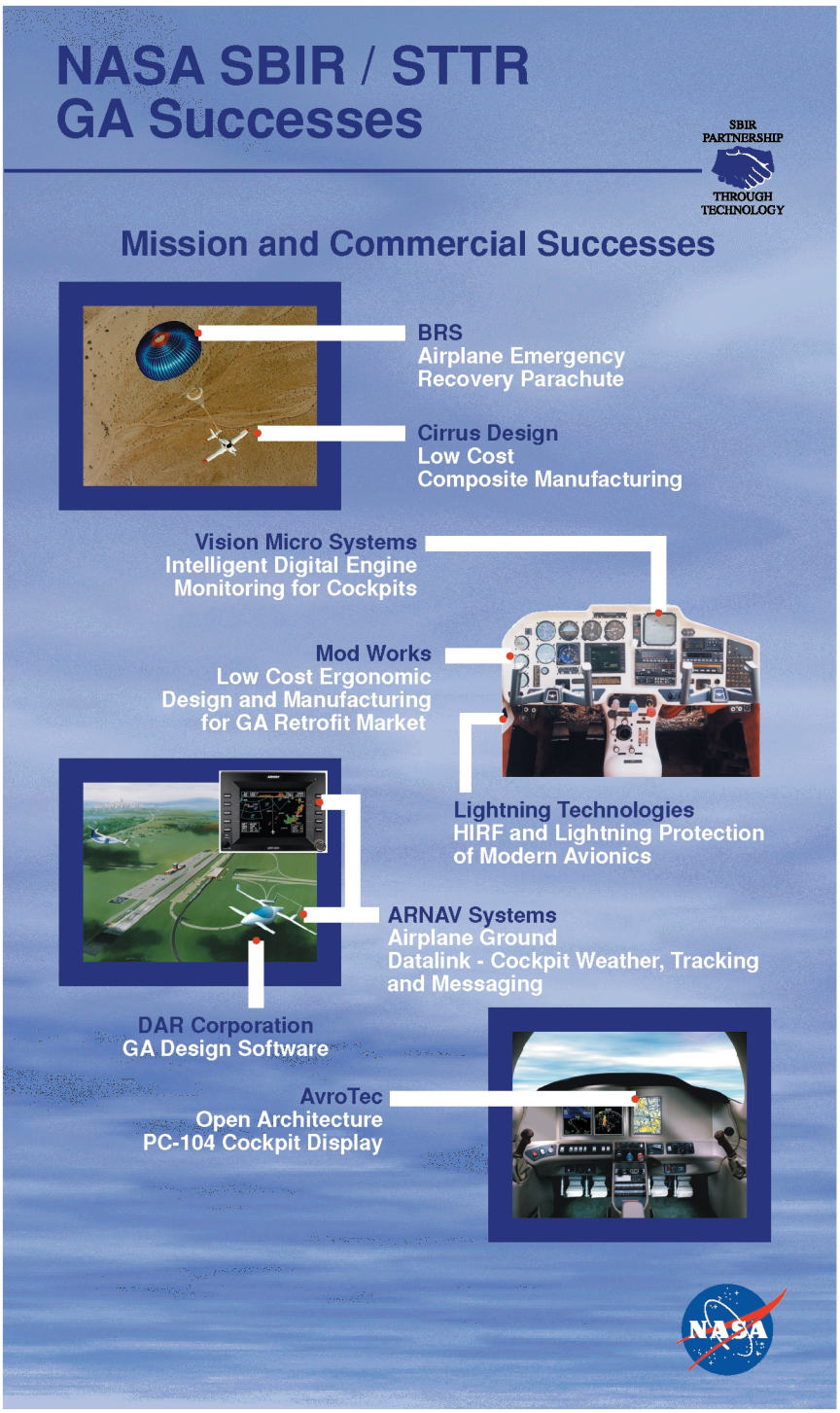
The stories that follow illustrate the recent contributions that the SBIR program has made to NASA missions and programs.

General Aviation, the AGATE Consortium, and the SBIR and STTR Programs

NASA mission programs are looking for SBIR and STTR developed technologies to meet programmatic objectives. SBIR and STTR technologies have been shown to be an effective way—both in terms of cost and technical parameters—to help meet mission requirements. As an example, the General Aviation (GA) revitalization effort at Langley Research Center has successfully leveraged the SBIR and STTR programs to obtain new technologies.

The GA revitalization effort, embodied in the AGATE (Advanced General Aviation Transport Experiments) consortium, has strategically leveraged the SBIR and STTR programs to support its efforts. The GA projects have received more the $34 million in SBIR and STTR funds from 1993 to 1998. The funds went directly to SBIR and STTR award winners, the small businesses that worked on the problems specified as subtopics in the SBIR and STTR solicitations.

The AGATE program is a consortium of over 70 members from industry, universities, NASA, the Federal Aviation Administration, and other government agencies. Its goals are to help revitalize the ailing aviation industry by developing affordable new technologies and advocating new standards and certification methods for next-generation single-pilot, near all-weather, light aircraft.



Companies that address the revitalization effort and win SBIR phase II contracts automatically become part of the consortium. These companies then have a pathway to the development of partnerships and other business relationships through the consortium. The GA and AGATE programs' strategic approach to leveraging the SBIR and STTR programs has led to some impressive results. One example of both the benefits of SBIR and

STTR and the AGATE consortium is Cirrus Design Corp.'s SR20 aircraft.

The SR20 is a four-seat single-engine aircraft that was designed with innovative improvements in speed, comfort, and safety. The company has over 500 confirmed orders for the SR20 aircraft and production has been consistently increasing over the past year.

Cirrus Design was awarded two SBIR phase II contracts that developed innovative manufacturing techniques. In addition, the innovations of several other SBIR companies are integral parts of the aircraft. A few of the new technologies are discussed in the following paragraphs.

The SR20 includes as standard equipment an aircraft emergency recovery parachute that was developed by Ballistic Recovery System (BRS) in part through an SBIR contract with the Langley Research Center. The SR20 parachute is known as CAPS—the Cirrus Airframe Parachute System. BRS has a $1 million contract with Cirrus to supply the parachutes for the SR20.

The BRS parachute is also used in over 25 small experimental airplanes, which provides BRS with approximately $1 million in revenue per year. More importantly, the BRS system is a proven lifesaver. BRS has over 100 stories from pilots who have survived crashes because they had a BRS parachute system in their aircraft.

ARNAV Systems Inc. is another company that has technology incorporated into the SR20 aircraft. Through its SBIR project "Affordable Electronic Weather Reporting System for General Aviation Pilots," ARNAV developed innovative "weather in the cockpit" technology. This technology is a low-cost data link that provides weather information graphically to the cockpit. ARNAV has since expanded the application and has developed a cockpit multifunction display (MFD) which includes the weather in the cockpit function. ARNAV's MFD has been incorporated into the SR20 avionics system.

ARNAV has applied this technology to other efforts. For the 1996 Summer Olympics in Atlanta, Operation Helistar, an AGATE-based effort, required that all aircraft flying over the games be equipped with an ARNAV data link. This link provided both weather and traffic information graphically to each cockpit. The AGATE ground control station had two-way text messaging capability with the aircraft as well, thus increasing the safety of the many planes and helicopters over Atlanta.

In 1999, ARNAV continued to expand the availability of up to the minute weather data to the general aviation community when it was awarded a 5-year Flight Information System (FIS) contract with the Federal Aviation Administration (FAA). Under the contract, ARNAV will receive two nationwide data link frequencies on which to broadcast basic aviation weather reports. FIS is considered fundamental to the National Airspace System architecture modernization program.

The GA and AGATE programs' success is not limited to technologies incorporated into the Cirrus SR20, nor has the SR20 been the only example of SBIR companies partnering (and thus increasing the success of both). Several other innovations have improved the safety, reliability, and cost-effectiveness of small aircraft.

Mod Works and Vision Micro Systems joined forces in the creation of Mod Works' human factors engineered ergonomic instrument panel. This panel includes Vision Micro System's intelligent digital engine monitoring system for small airplanes. This low-cost system reduces the pilot's engine management workload and improves operation safety and reliability. Mod Works' manufacturing technology, which was developed under the STTR program, is key to the company's ability to produce the instrument panel at a low cost.

The instrument panel received FAA certification and has found a market in the retrofitting of older planes. In addition, Mod Works used the technology in a different product when it developed an FAA certified training simulator. The simulator has the same type of ergonomic instrument panel that was incorporated into the aircraft—hence the market appeal of the simulator. Over 250 simulators have been built and shipped in the last few years.

Innovative Dynamics Inc. (IDI) has been working on ice protection technology through the SBIR program at Glenn Research Center for several years. IDI has developed a sensor system that assists in the detection of ice buildup, as well as in determining if the accreted ice has been shed after system operation. The technology has been licensed to B.F. Goodrich and integrated into its pneumatic deicers, which has brought ice detection technology to general aviation at an affordable price.

AGATE has shown that the inclusion of SBIR in strategic planning is a way for programs and projects to gain access to additional resources and to bring in small businesses which, in turn often bring novel ways of solving problems. Other NASA programs are now trying to emulate AGATE's success.

A large portion of the total GA revitalization is yet to be solved. There are over 5000 public aviation landing facilities within the United States and most are underused because of limited systems capabilities. The Small Aircraft Transportation System (SATS) is a NASA initiative that focuses on these challenges with a goal of increasing personal mobility by providing affordable all-weather use of the Nation's public landing facilities and better integration of small aircraft into our air transportation system. Technology areas include the integration of safe, low-cost, and easy-to-fly aircraft with smart, small airports. The SATS team will continue to form partnerships with the SBIR program.

Other Centers are learning from AGATE's successful utilization of the SBIR Program. The Kennedy Space Center is including the SBIR program as one of the strategic resources in its plan for acquiring technologies in support of the Spaceport Technology Center. The Spaceport Technology Center is envisioned as a world class resource for the emerging space transportation industry. It is dedicated to furthering the visionary approaches and strategies for developing the technologies for future spaceports. Such spaceports will help space flight become so affordable that industry will be able to take advantage of it for research, manufacturing, and human exploration.

Emerging spaceport technologies that are conducive to SBIR and STTR businesses include new techniques, methods,

"The NASA SBIR program has allowed Mod Works to build a world class engineering team. We can now compete globally."

Tim Coons
President
Mod Works

mechanisms, and machinery to process space cargo, and space vehicles, as well as technologies to launch and land space vehicles.

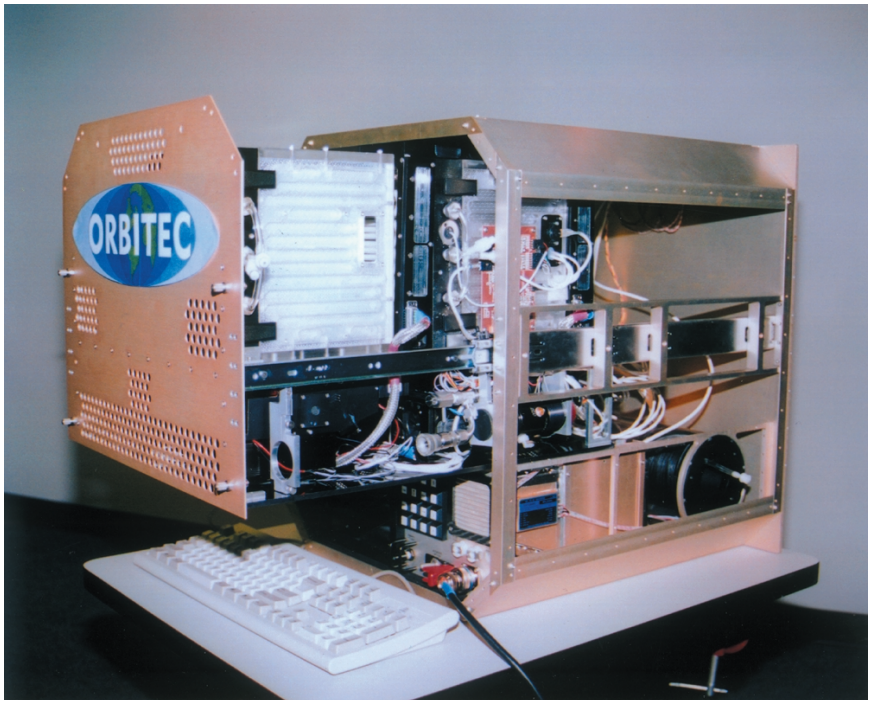
International Space Station Applications

The International Space Station Program is another example of a NASA project that is very successfully making use of SBIR innovations.

The International Space Station will make long term scientific experimentation a reality. To prepare for that, the Space Station Biological Research Project (SSBRP) team at Ames Research Center was tasked to design and build experimentation facilities to aid in the study of the fundamental impact of gravitational forces on living systems, from single cells to entire systems of plants, animals, and humans.

Over the last several years, three SBIR companies have been awarded significant phase III contracts to develop the necessary research hardware. The SSBRP has used these companies to assist in achieving its goals for experimentation facilities. SSBRP worked with the SBIR companies for several reasons—primary among those reasons was that the companies had proposed strong and innovative approaches to the challenges posed. In addition, the smaller companies were able to implement their programs with a level of cost efficiency and design flexibility that would be difficult for a larger aerospace company to achieve.

The three SBIR companies participating in the SSBRP activities are STAR Enterprises of Bloomington, Indiana; Space Hardware Optimization Technology (SHOT) Inc. of Floyd Knobs, Indiana; and Orbital Technologies Corporation (ORBITEC) of Madison, Wisconsin. The total value of the contracts awarded to these companies is in excess of $95 million.



STAR Enterprises is developing an advanced animal habitat for rats and mice that will be used for both basic and biological research. The habitat will allow both scientists on Earth and astronauts to view the animals and monitor their physiology and behavior while the rodents live under microgravity or under different levels of artificial gravity created when the habitat is attached to the Space Station's centrifuge.

SHOT is developing two avian habitats for the Space Station Gravitational Biological Facility. In addition to this direct contract, SHOT also has a significant role as a subcontractor in the STAR contract.

ORBITEC's work is in plant growth facilities. Its contract with SSBRP is for the delivery of a multifunctional plant research facility for the Space Station. This facility will provide life support for a variety of plants; the capability to conduct experiments in microgravity; and the capability to collect, record, and transmit science and engineering data—including video—to ground stations.

Through experience, the SSBRP has learned that working with SBIR companies can have great benefits. The project estimates that it has saved several million dollars by contracting with the SBIR companies. In addition, the use of the phase III contracting mechanism reduces the contracting time significantly, which, for a project like Space Station with critical launch dates, can be very important.

The New Millennium Program's Deep Space I

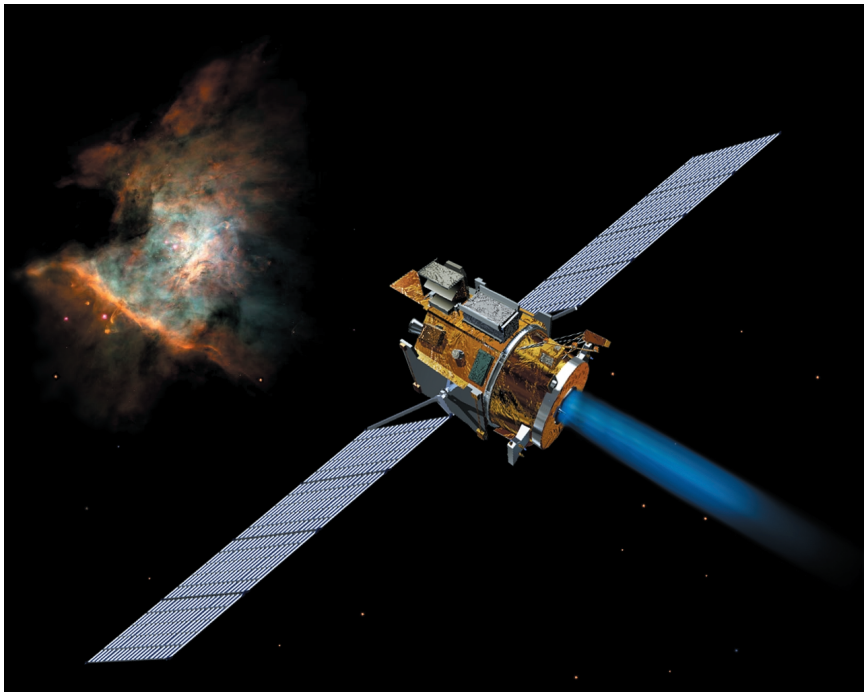
Deep Space 1, the first New Millennium Program project to be launched, benefited from two technologies that began with the SBIR program. One technology is integral to the operation of the spacecraft; the other is one of the demonstration instruments that was part of the science mission.

Entech Inc. started work on its domed/arched Fresnel optics for space applications through a Glenn Research Center SBIR contract that was awarded over 15 years ago. That concentrator lens work has evolved into the key element of the Solar Concentrator Array with Refractive Linear Element Technology® or SCARLET solar array, which powers Deep Space 1.

The SCARLET solar array can reduce, typically by a factor of 8 to10, the amount of solar cells necessary to generate a given amount of power. The array does this by using a unique refractive lens system that concentrates sunlight like a magnifying glass onto a line of smaller high efficiency solar cells, essentially replacing the solar cells with lightweight, inexpensive concentrator optics. Because of its high performance, the array can be small and, since solar cells are the most costly part of an array, overall costs can be significantly reduced.

Under another government contract, Entech teamed with ACE-Able Engineering Co., specialists in solar arrays and space structures, to develop and build SCARLET for the Deep Space 1 mission. Launched in October 1998, this array was the first refractive photovoltaic concentrator array to be used as the primary power source for a spacecraft. Its unprecedented success and flawless operation has laid the groundwork for the possible use of concentrator solar arrays for future government and commercial space missions.

The Deep Space I with refractive solar arrays and a miniature integrated camera spectrometer.



On board the Deep Space 1 spacecraft is an instrument known as the miniature integrated camera spectrometer or MICAS. The MICAS instrument was constructed by using silicon carbide composites, which yielded a multipurpose instrument that costs 10 times less and consumes 10 times less power than conventional instruments that perform the same tasks.

The innovative technology used in the construction of the MICAS instrument by SSG, Inc. was developed under an SBIR contract with the Jet Propulsion Laboratory. With SBIR support, which began in 1992, SSG Inc. developed technology for building telescopes, including visible quality mirrors, from silicon carbide composites. In addition to the weight savings, the composites display exceptional stability during changes in temperature.

Both of these SBIR related technologies have performed exceptionally well and are great examples of the value SBIR developed technologies bring to NASA.

Commercial Success Stories

While NASA utilization is one objective of the SBIR and STTR programs, another, equally important goal, is that of developing commercially viable products based on the technologies developed through SBIR research. The following stories highlight technologies developed at least in part through NASA SBIR and STTR contracts which have evolved into products that could touch all our lives.

Refrigeration System Additive

In the late 1980's, Mainstream Engineering received an SBIR award from Goddard Space Flight Center to develop a chemical and mechanical heat pump. As an indirect result of that effort, Mainstream developed QwikBoost™, an additive for vapor-compression refrigeration systems, air conditioners, and heat pumps that increases system performance and consequentially reduces overall energy consumption.

In essence the additive works by increasing the cooling capacity of the refrigerant. The additive circulates through the refrigeration system similar to the way the lubricant circulates. It has a high affinity for liquid hydrofluorocarbon and hydrochlorofluorocarbon refrigerants and exhibits a significant heat of solution when mixed with them. This solution heat increases the available cooling capacity (latent heat) of the refrigerant during evaporation, which provides an increase in performance of the system.

The additive has been shown to be environmentally safe with zero ozone depletion potential and has been shown to improve the performance of vapor-compressor heat pumps, air conditioners, and refrigeration systems by as much as 20 percent. Additionally, the additive remains active for the life of the system and does not need to be replaced once it is introduced into a system.

NASA and other government applications are numerous, including vapor-compression thermal control systems for spacecraft, which result in lower mass systems, and hence lower launch costs. The product is also in use in air conditioning and refrigeration systems at NASA facilities, which results in annual energy savings.

Chemical heat pump being added to a system.

Photodynamic Therapy

In the mid-1990's, Quantum Devices of Barnveld, Wisconsin, began working with the Marshall Space Flight Center (MSFC) through the SBIR program to develop plant growth technology for Space Shuttle experimentation. Quantum Devices' focus was on photodynamic therapy or PDT. The company developed a compact, highly reliable light source for PDT: a light-emitting diode (LED) probe. The company has since applied this technology for medical applications—specifically cancer treatment and wound healing.

In its work in cancer treatment, Quantum Devices uses its LED probe to activate photosensitizers—light sensitive, tumor treating drugs. The LED activation process allows the drugs to destroy cancerous cells and leave the surrounding, healthy tissue virtually untouched. While lasers have been used for this type of treatment, the LED probe has been shown to have significant advantages.

Compared to lasers, the LED has proven to be more mechanically reliable. It is also smaller—the whole system is about the size of a briefcase—and is less expensive to use. In terms of improved medical effectiveness, the LED probe produces a longer wavelength, broad spectrum, near-infrared light that allows for wider and deeper penetration of the drug therapy.

The positive results achieved by Quantum Devices have led the company to start obtaining the necessary approvals from the Food and Drug Administration (FDA) for more widespread usage. Currently, the probe is approved for use in certain cases where all other methods of treatment have been exhausted. In addition, cancer treatment trials are underway.

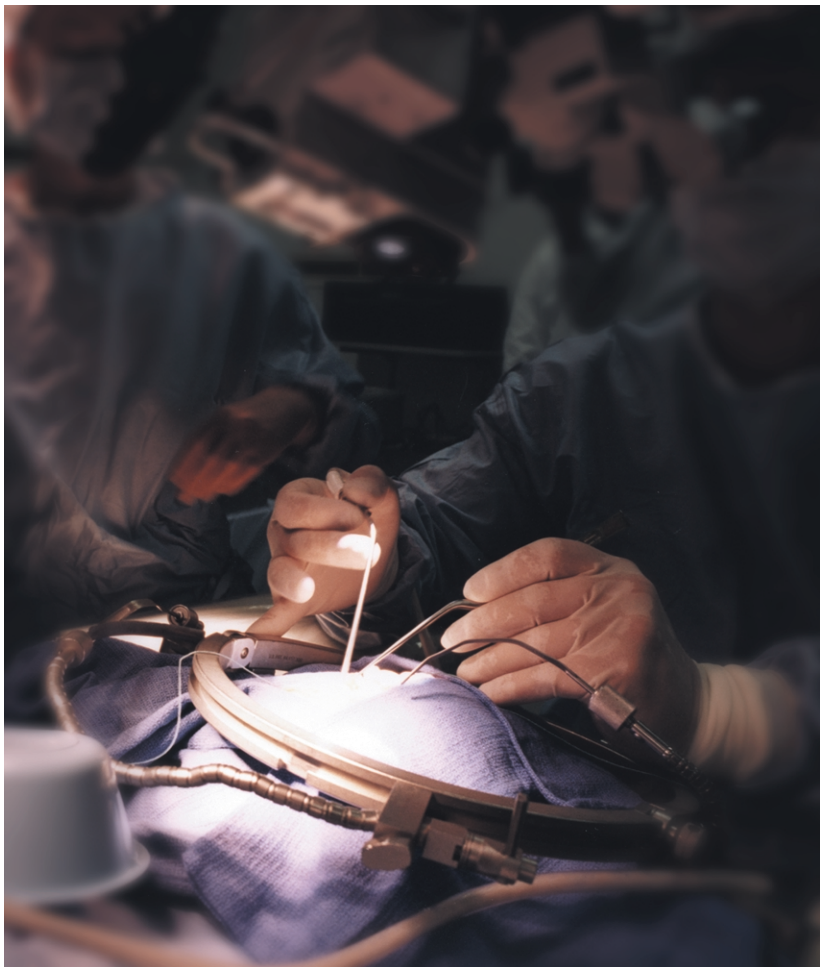
Results to date have been very positive. For example, in May 1999, a young woman with an aggressive form of brain cancer was treated with a photosensitized chemotherapy drug that was then activated by the LED probe. She has since fully recovered from the operation and there is no evidence of the tumor returning. Prior to the LED operation, this patient's 10-year battle with the cancer had included six surgeries, chemotherapy, and radiation treatments.

Quantum Devices has recently expanded LED-based treatments to the area of wound healing. NASA has an interest in wound healing because wounds are slow to heal in a microgravity environment. As in the case of cancer treatment, laser-based wound healing has been investigated, and again, the LED-based therapy has been shown to be an effective alternative. Lasers possess problematic characteristics that the LED does not, including limitations in wavelength and beam width. In addition, larger wounds can be treated with flat arrays of LED's.

NASA and Quantum Devices are currently engaged in a phase II SBIR contract to further the study of wound healing with the LED-based technology. One of the objectives of this work is to undertake human clinical trials.

While the medical applications of the LED technology are very exciting, it should also be noted that the original objective of the work for NASA has also been successful. Plant growth is essential to long term space habitation, and Quantum Devices' LED has flown on multiple Space Shuttle

Light-emitting diode (LED) probe used in the photodynamic therapy treatment of cancer.



Applying light-emitting diode (LED) technology to heal wounds.

missions inside the Astroculture™ plant growth chamber. Quantum Devices' work with LED's is a great example of how SBIR developed technology can have benefits not only for NASA but also for the Nation.

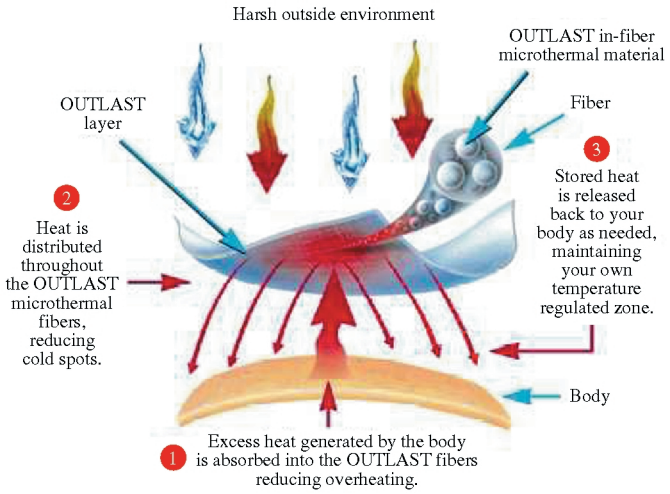
Phase Change Material for Insulation

Due to the 400-degree difference between light and shadows on the moon, NASA needed an innovative thermal regulation system that could significantly out perform traditional lofted insulation. The technology developed—called phase change material or PCM—was the outcome of SBIR-sponsored work.

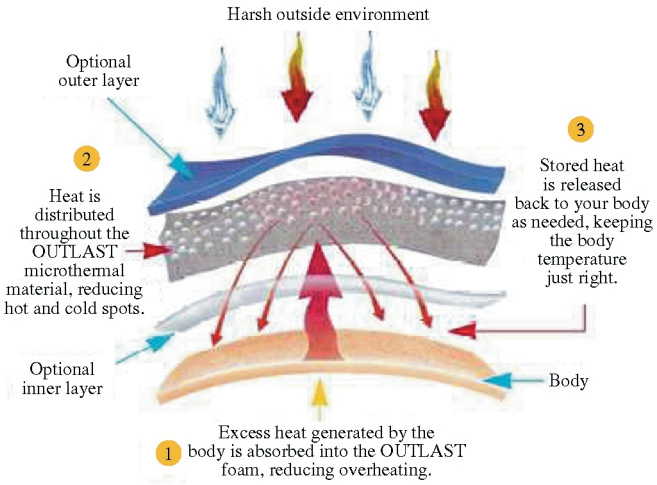
This technology was developed for NASA through an SBIR contract with Triangle R&D Corporation in conjunction with Johnson Space Center. In 1991, exclusive license to this technology was granted to OUTLAST from Triangle R&D Corporation. Since that time, OUTLAST has partnered with over 150 manufacturers and suppliers to market the product.

The PCM is essentially a nontoxic paraffin wax that is encapsulated in a plastic shell. PCM's are microscopic in size—thousands fit on the head of a pin. The paraffin wax changes from a liquid to a solid state, and back again, due to changes in temperature, which allows storage and recycling of body heat. The PCM's exchange large amounts of energy (heat) during this process. This exchange process happens continually and allows the user to maintain a fairly constant body temperature over a broad range of environments and exercise levels. PCM's can be applied to fibers, fabric, and foam, making it very versatile. Current applications include a wide variety of gloves, boots, jackets, and blankets.

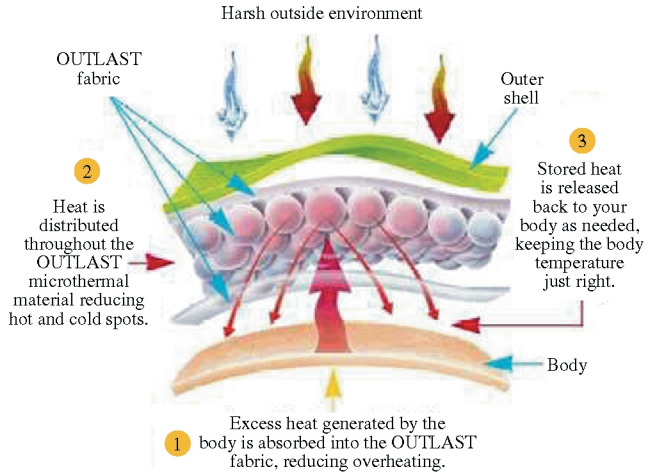
OUTLAST is proud to be a member of the NASA-sponsored U.S. Astronaut Hall of Fame in recognition of flight gloves made from PCM material. Ski equipment made from PCM material was voted Best Innovation for the New Millennium by *Skiing* magazine and was also included as one of the best products of 1999 by *Business Week* magazine (Dec. 20, 1999).



Phase change material used in fiber.



Phase change material used in foam.



Phase change material used in fabric.

Robotic Surgical Assistance

Computer Motion, Inc. of Goleta, California, has developed, with the assistance of two SBIR contracts from the Jet Propulsion Laboratory (JPL), a suite of computer enhanced and robotic surgical assistance systems. Studies have shown that these systems not only enhance the surgeon's capabilities, but also improve patient outcomes and reduce costs.

JPL's first SBIR contract with Computer Motion supported the development of the automated endoscopic system of optimal positioning or AESOP. In endoscopic procedures, a thin probe called a laproscope with a miniature camera attached is surgically placed inside the patient. This allows the surgeon to view the surgical field on a television monitor. The AESOP positions the laproscope where the surgeon wants it. Prior to the development of AESOP, a surgical nurse would position and hold the laproscope. By using AESOP, the surgeon can control the laproscope directly and the naturally occurring unsteadiness of the human hand is eliminated.

In 1995, AESOP received approval from the Food and Drug Administration (FDA). In many hospitals it is now routinely used

for gall bladder operations, hernia repair, and other laproscopic-based surgeries.

A second SBIR contract with JPL allowed Computer Motion to demonstrate a number of important enhancements to AESOP. There were three improvements that the SBIR contract contributed to: additional robotic manipulators or arms that are controlled by the surgeon, the ability of the surgeon to use voice commands to control the position of the laproscope, and finer controls of the robotic arms. The finer control mechanisms allow for the filtering out of tremors to the level of steadiness necessary for microsurgical suturing.

These improvements have been incorporated into a new device called ZEUS. The ZEUS has three interactive robotic arms, a computer controller, and a console. Using ZEUS, the surgeon is situated at the console to control the movements of two of the robotic arms that perform the procedure. The console includes handles, resembling conventional surgical instruments, that are used to control the robotic arm movement of the actual surgical instruments. The third arm provides the surgeon with voice controlled visualization of the procedure.

Both AESOP and ZEUS have been applied to heart surgery. Computer Motion has recently completed three clinical series totaling more than 300 minimally invasive mitral heart valve surgeries with AESOP. The AESOP system allows the surgeon to perform these operations though a small incision (4 to 6 cm) rather than fully cutting open the chest. The AESOP endoscope provides the surgeon with a clear, motionless view of the surgical area, which the trials showed lead to a significantly (approximately 20 percent) reduced operation time. The smaller incision also results in faster recovery times for patients.

ZEUS is also pushing the envelope for heart surgeons. It completed, in the spring of 2000, an FDA-approved phase 1 investigational device exemption study. At the London Health Sciences Center in Ontario, Canada, several patients have benefited from ZEUS. In those cases, the patients have undergone beating heart bypass surgeries. Previously, all bypass patients were put

Robot Surgical System (ZEUS™).

on a heart-lung machine during their surgeries, but with ZEUS, surgeons have been able to perform the necessary work while the heart is still beating and pumping blood.

While still very much in the trial stages, the ZEUS technology holds promise for vastly improving patient results in specific types of bypass surgeries. The ZEUS removes two of the elements of the procedure that greatly affect recovery time —the large incision and the trauma to the chest that goes along with it and the use of the heart-lung machine. Patients who had this experimental bypass procedure reported that they had minimal pain after the surgery and some were able to return to work with in a week.

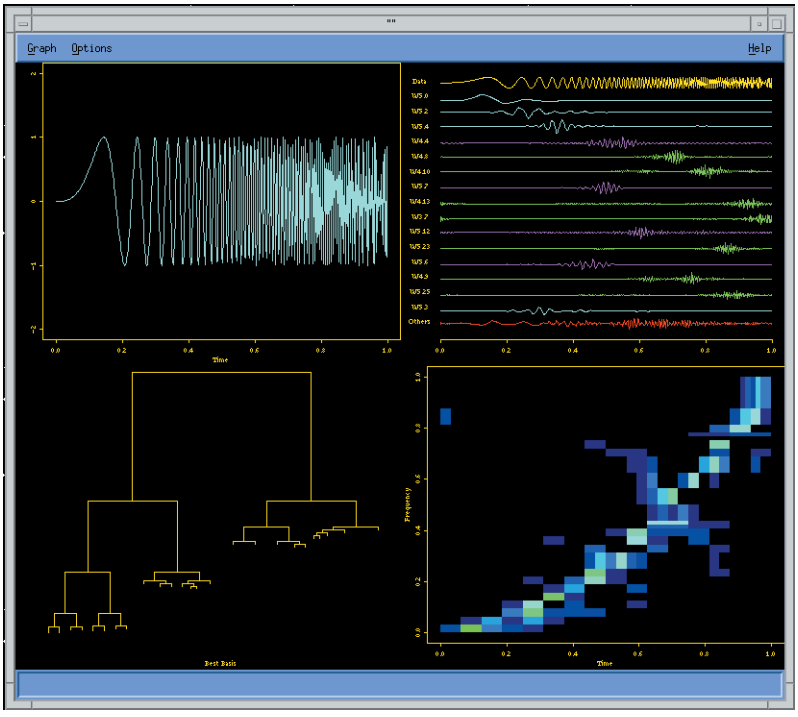
Wavelet Analysis

Wavelet analysis is a growing area of focus in the mathematical and research communities. The study of wavelets as a distinct discipline began in the late 1980's.

Wavelet analysis is the use of linear combinations of wavelet functions to represent signals. These representations are very useful for a broad range of data analysis applications such as data compression, signal and image processing, and nonparametric statistical estimation.

Wavelet analysis has some significant advantages over more traditional methods such as Fourier analysis. For example, wavelets are localized in time. They are good building block functions for many types of signals, including those that have jumps or other non-smooth traits, which are not well suited to Fourier series approximations.

As the field of wavelet analysis became more developed, the need for a package that included all of the utilities of wavelet functions in one collection increased.



This screen demonstrates the best wavelet packet analysis of a quadratic chirp signal using S+ Wavelets software.

Addressing that need was the objective of an SBIR contract that the Stennis Space Center awarded to the StatSci Division of Mathsoft, Inc. StatSci developed, with the assistance of the SBIR contract, the first commercially available computer software application that provides users with a comprehensive wavelet analysis toolbox. The product is called S+Wavelets. S+ Wavelets software offers the user more sophisticated methods of analysis; users can view and explore details in data that other techniques may miss or lose.

S+Wavelets software was designed to be an add-on module to the company's popular S-PLUS software program, which is one of the most powerful data analysis packages available. Scientists, data analysts, and engineers who use S-PLUS software can add S+Wavelets software and have a more powerful tool. Since the initial release of S+Wavelets software, it has been modified so that now it can also be purchased as a module for Mathsoft's MathCad software. MathCad software is a mathematical and engineering package for personal computers.

In addition, a manual *Applied Wavelet Analysis with S-PLUS* was published through an SBIR contract with Stennis. This manual takes a visual approach to wavelet analysis with less emphasis on the mathematics and more on the actual uses of wavelet analysis.

Since its initial release in 1995, hundreds of copies of S+Wavelets software have been sold both in the US and worldwide. Thousands of copies of *Applied Wavelet Analysis with S-PLUS* have also been sold.

Water Analyzer

Applied Spectrometry Associates (ASA) Inc., a Waukesha, Wisconsin based company, is successfully commercializing water analyzers that were originally designed under an SBIR contract sponsored by the Kennedy Space Center (KSC).

The analyzer, known as ChemScan®, is a process analyzer that uses ultraviolet spectrometry and specially designed software to detect dissolved nutrients, organics, and metals in municipal or industrial water and wastewater plants. The system provides an online, real-time monitoring capability. Online management of the system can be managed either at the specific plant site or from a remote location.

Originally developed as a water chemistry analyzer to provide real-time monitoring of plant nutrients in hydroponic solutions for the KSC Biomedical Office, the ChemScan® analyzer can detect any chemical substance that absorbs light in the ultraviolet or visible wavelength range. The system can detect, identify, and quantify various macronutrients within the absorption spectra. Other innovative aspects of this water analyzer include its low maintenance; it requires only a few hours a month for calibration verification and preparation of reagents. No time is needed for recalibration. In addition, the system uses multiple wavelengths for analysis thereby allowing for the simplification of testing processes.

ASA purchased the manufacturing rights for the ChemScan® analyzer from Biotronics Technologies Inc., which had done the original SBIR-funded research. Commercial ChemScan® analyzers are used to measure multiple chemicals at water treatment or wastewater treatment plants. There are now four models of the ChemScan® analyzer. The newest model, released in 1998, provides automatic analysis of ammonia or phosphate in water.

Over 100 ChemScan® systems have been installed at industrial and municipal facilities, including multiple parameter systems in major U.S. cities such as Phoenix, Arizona; Austin, Texas; Los Angeles, California; Gainesville, Orlando, and Tampa, Florida; and New York City. ASA has also had international sales, including in Canada and South Korea.

Ring Buffer Network Bus

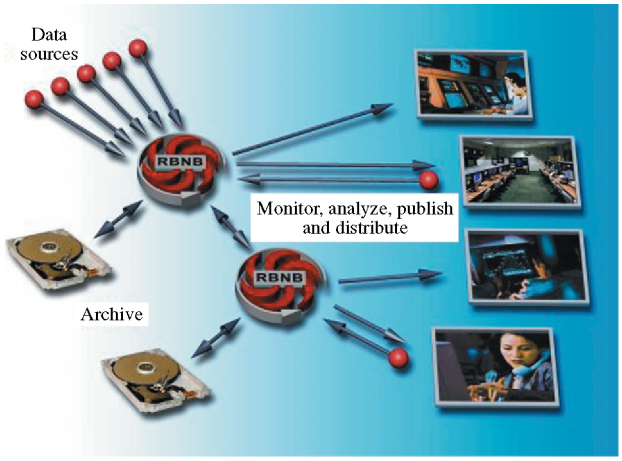
DataTurbine™ ring buffer network bus is a software server that was developed by Creare, Inc. of Hanover, New Hampshire in part through a SBIR contract with Dryden Flight Research Center. The DataTurbine™ server provides a buffered network data path between suppliers and consumers of information. It manages all aspects of interapplication data traffic, assimilating data acquisition, and network storage.

DataTurbine™ servers address the often conflicting problems of processing multiple data sources into a single data stream while providing fast, easy access to that data by many users. The software is a network data server that is inserted between the data sources and end users and manages data flows. DataTurbine™ servers enable real-time or request and response data exchange from point-to-point, one to many, or many to one sources.

DataTurbine™ servers enable remote monitoring, synchronized data distribution, application integration, and collaborative processing. In an initial NASA application, the ring buffer network bus (RBNB) software was set up in the Research Engineering Test Station (RETS) onboard an L-1011 aircraft to automate data analyses that previously could only be done after the flight was concluded. Engineers at Dryden were able to provide an immediate assessment of each aircraft maneuver as it occurred during the flight to test drag reduction technology.

Numerous DataTurbine™ servers are being used on the NASA DC-8 Airborne Science Flying Laboratory, the flight test mission control center, and remote sites at other NASA centers. Recently, an

Ring buffer network bus (RBNB) enables monitoring, data distribution, integration, and collaborative processing.

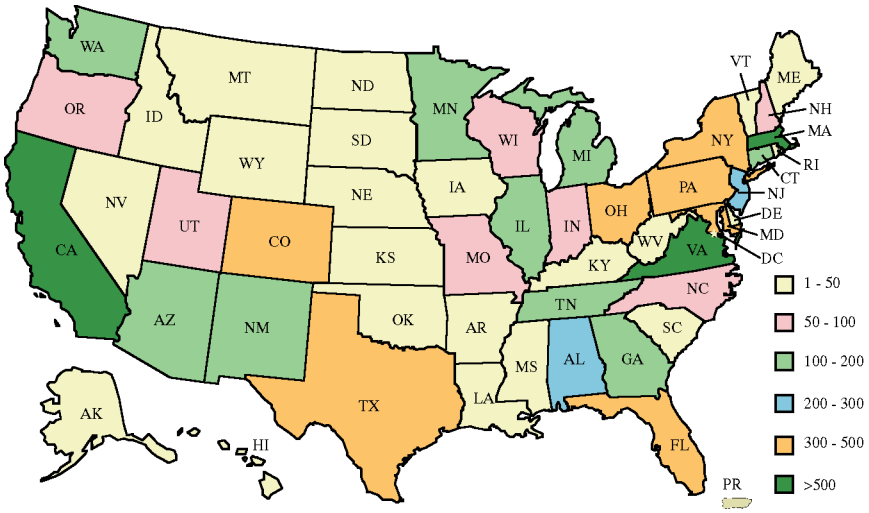


experiment, AeroSAPIENT, was conducted in the DC-8. This experiment was a collaborative effort between four NASA centers that explored the safety of, and data integrity of, digital aircraft communication systems for future aircraft.

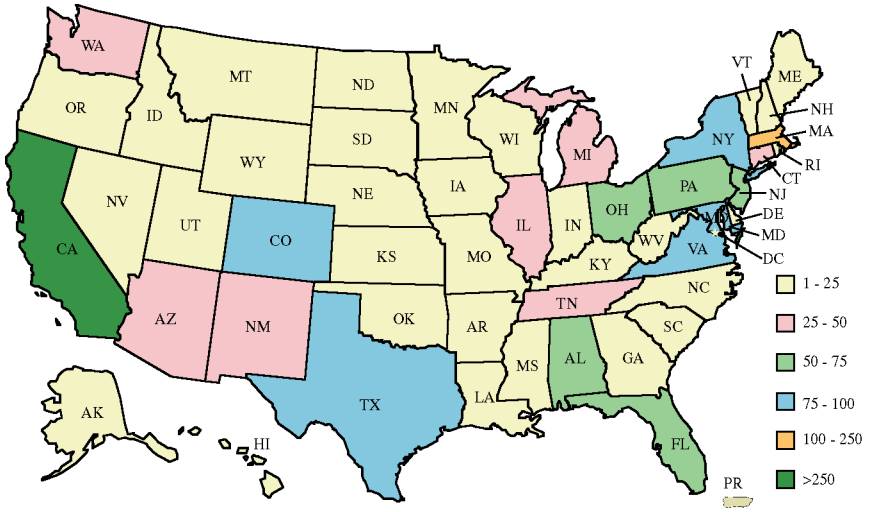
Dryden's current contract with Creare can be used by any U.S. Government agency. Glenn Research Center is using the contract for developing a next-generation engine test stand, and the Force Protection Battle Laboratory at Lackland Air Force Base is using DataTurbine™ servers as part of a prototype distributed command and control system. Lastly, the Department of Energy and the Air Force have SBIR activities that include DataTurbine™ servers.

DataTurbine™ servers won an honorable mention in NASA's 1999 Software of the Year competition. In addition, the patent pending technology was recently presented with an R&D 100 Award for 2000 from *R&D* magazine.

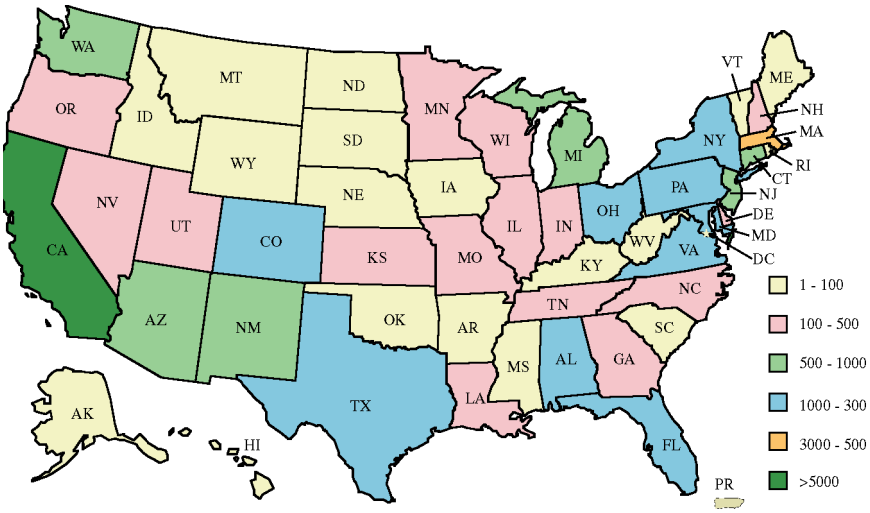
SBIR Distribution Maps



Distribution of SBIR firms from 1983 to 2000 (8,673 total).

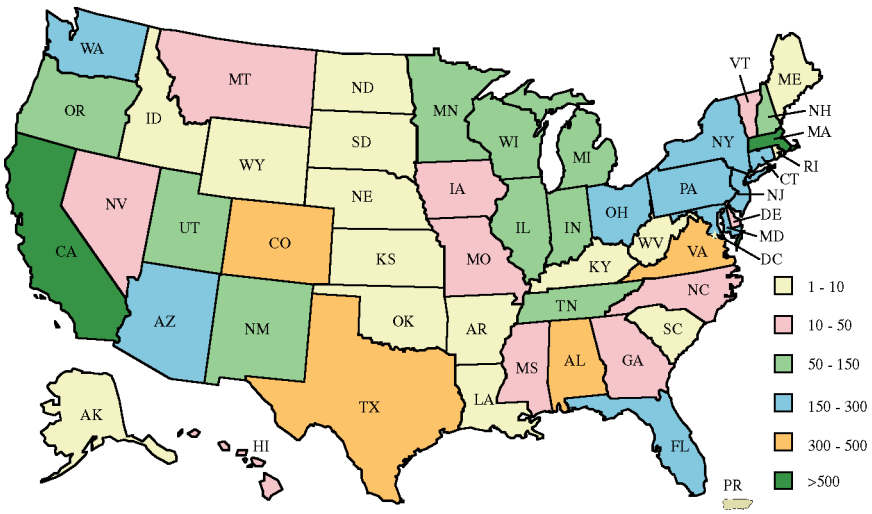


Distribution of SBIR awarded firms from 1983 to 2000 (1,832 total).

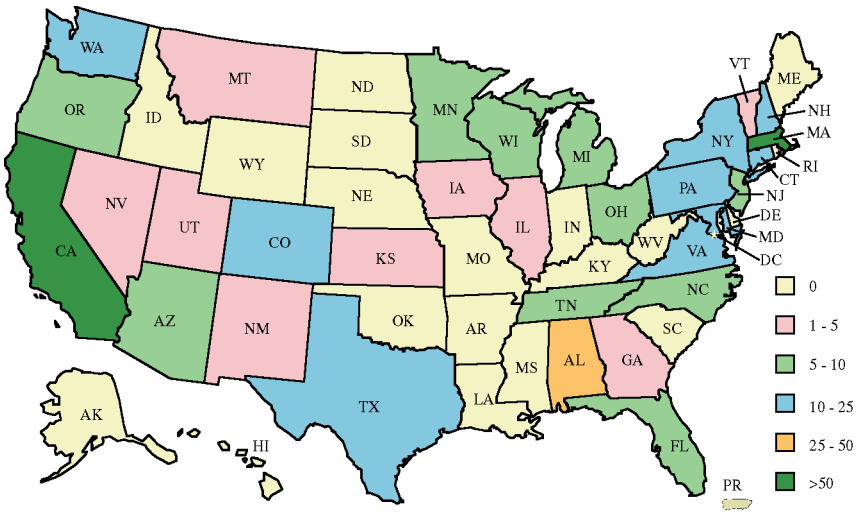


Distribution of SBIR phase I and phase II proposals from 1983 to 2000 (41,085 total).

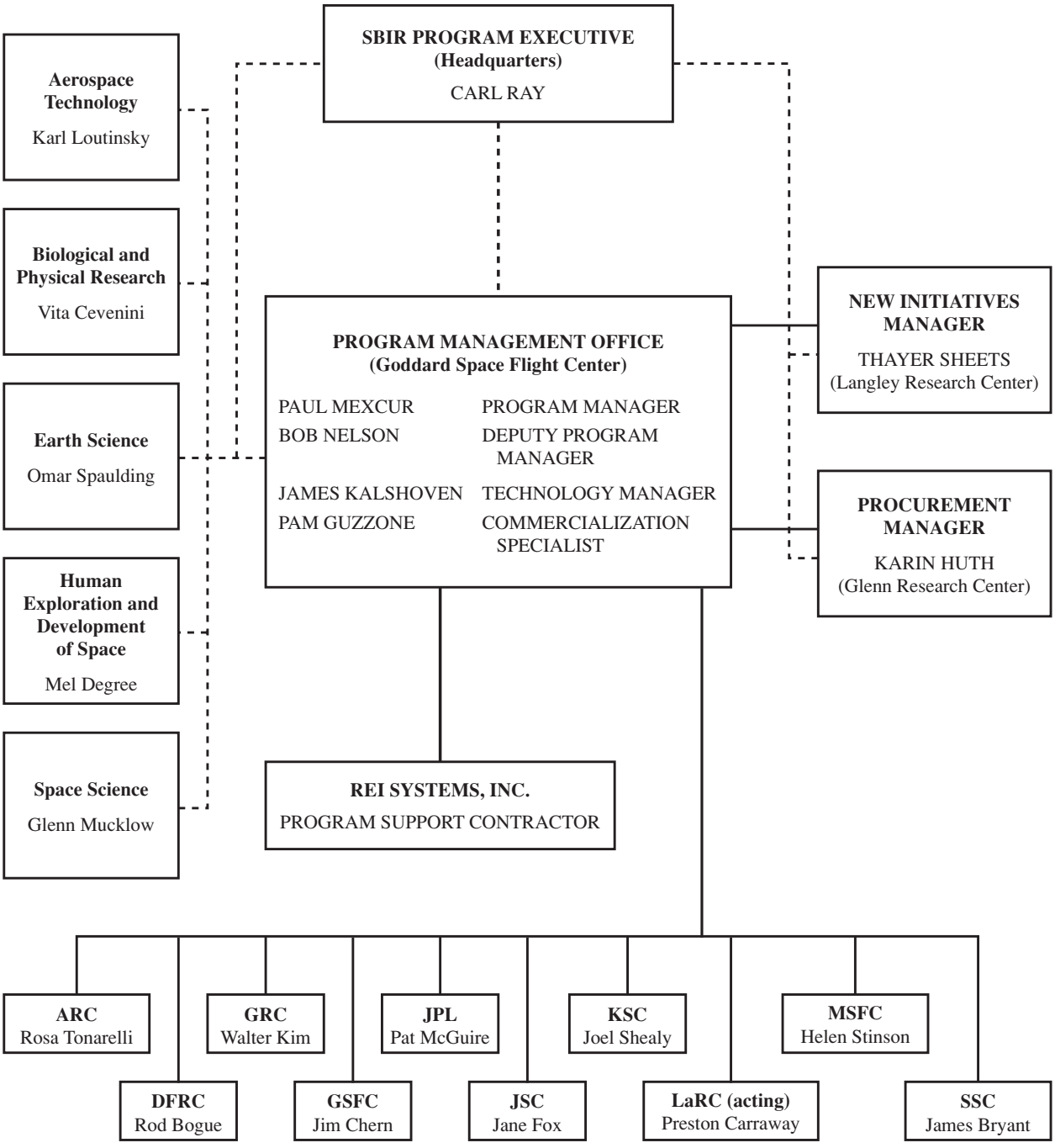
Distribution of SBIR phase I and phase II awards from 1983 to 2000 (6,957 total).



Distribution of SBIR success stories from 1983 to 2000 (348 total).



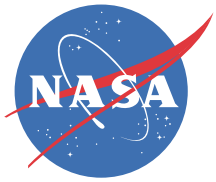
SBIR ORGANIZATION



SBIR Group Photographs

Program Management Office and Strategic Enterprise Representatives.

Field Center Program Managers.



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