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NASA JOHNSON SPACE CENTER SBIR STTR PROGRAM TECHNOLOGY INNOVATIONS

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ABSTRACT

The Small Business Innovation Research (SBIR) Program increases opportunities for small businesses to participate in research and development (R&D), increases employment, and improves U.S. competitiveness. Specifically the program stimulates U.S. technological innovation by using small businesses to meet federal R&D needs, increasing private-sector commercialization of innovations derived from federal R&D, and fostering and encouraging the participation of socially disadvantaged businesses. In 2000, the Small Business Technology Transfer (STTR) Program extended and strengthened the SBIR Program, increasing its emphasis on pursuing commercial applications by awarding contracts to small business concerns for cooperative R&D with a nonprofit research institution. Modeled after the SBIR Program, STTR is nevertheless a separately funded activity. Technologies that have resulted from the Johnson Space Center SBIR STTR Program include: a device for regenerating iodinated resin beds; laser-assisted in-situ keratomileusis or LASIK; a miniature physiological monitoring device capable of collecting and analyzing a multitude of real-time signals to transmit medical data from remote locations to medical centers for diagnosis and intervention; a new thermal management system for fibers and fabrics giving rise to new line of garments and thermal-enhancing environments; and a highly electropositive material that attracts and retains electronegative particles in water.

1. INTRODUCTION

The U.S. Congress established the Small Business Innovation Research (SBIR) Program in 1982 to provide increased opportunities for small businesses to participate in research and development (R&D), increase employment, and improve U.S. competitiveness. Specific objectives of the SBIR Program are to stimulate U.S. technological innovation, use small businesses to meet federal R&D needs, increase private-sector commercialization of innovations derived from federal R&D, and foster and encourage participation by socially disadvantaged businesses. Legislation enacted in 1992 extended and strengthened the SBIR Program, increasing its emphasis on pursuing commercial applications of SBIR project results.

Federal agencies with R&D budgets exceeding \$100 million are required to implement SBIR programs. Funding is provided by allocating 2.5%

of each agency's extramural R&D budget to SBIR. Each agency administers its own individual program within guidelines established by the Small Business Administration (SBA). The SBA is responsible for establishing governing policy and for overall program monitoring, reporting, and analysis.

The structure of the SBIR Program reflects the Congressional understanding that the processes of innovation and bringing new products to the marketplace have a high degree of technical and financial risk. The program, therefore, has three phases: Phase 1 is the opportunity to establish the feasibility and technical merits of a proposed innovation. Selected competitively, NASA's Phase 1 contracts last for 6 months and, in the foreseeable future, will not exceed \$100,000. Phase 2 is the major R&D effort. It continues the most promising of the Phase 1 projects based on

scientific and technical merit, expected value to NASA, company capability, and commercial potential. Phase 2 places greater emphasis on evidence of commercial development than Phase 1, particularly for NASA uses. Phase 2 contracts typically last 24 months and may not exceed \$750,000 at NASA. NASA usually selects approximately 40% of its Phase 1's to go on to Phase 2. Phase 3 is the infusion and use of the product into regular NASA programs and/or into the commercial market. Further development of the product to make it viable may be needed. NASA is able to accelerate the procurement process by recognizing that the Phase 1 and 2 competitions have met the federal competition in contracting requirements. Private-sector investment, in various forms, is also a vehicle for the Phase 3 process.

Each SBIR Program cycle begins in the spring with the issuance, on line at <http://sbir.nasa.gov>, of an SBIR Program Solicitation for Phase 1 proposals. The solicitation provides basic information about the SBIR Program including eligibility requirements, detailed instructions for preparing and submitting Phase 1 proposals, procedures used in proposal evaluation and selection, and information related to subsequent Phase 2 proposals and Phase 3 activities. The bulk of the document is devoted to describing the agency's needs for R&D in areas covered by the solicitation.

The Small Business Technology Transfer (STTR) Program involves a unique partnership between small business and a nonprofit research institution. The STTR Program awards contracts to small businesses for cooperative research and development with a nonprofit research institution (RI), such as a university. The goal of the

Congress in establishing the STTR Program is to facilitate the transfer of technology developed by a RI through the entrepreneurship of a small business. The small business and its partnering institution are required to sign an agreement on how intellectual property will be shared between them. Modeled after the SBIR Program with the same basic requirements and phased funding structure, STTR nevertheless is a separate activity that is separately funded. It differs from SBIR in several important aspects.

STTR is a smaller program. The funding set-aside is 0.15 % of the extramural R&D budget, approximately one-twentieth of the amount for SBIR. A small company must take the research and intellectual property of the research institution and convert it into a useful product. The small business and its partnering institution are required to sign an agreement on how intellectual property will be shared between them. In comparison to SBIR, twice as much time is allowed for performance of the Phase 1 activity. Also, while the proposal is submitted by the small business concern (SBC), at least 30% of the funding and work must originate with the RI, while only a minimum of 40% must come from the SBC. Phase 1 STTR projects receive up to \$100,000 in funds for a 1-year effort. Phase 2 is limited to \$750,000 for 2 years.

STTR solicitations are based on the NASA Centers of Excellence, one of which is located at each NASA field installation. The STTR Program alternates between several NASA installations for the topics of Centers of Excellence each year. There are no subtopics for STTR Program.

2. NASA SBIR STTR PROGRAM

Within NASA, the Aeronautics Research, Exploration Systems, Science, and Space Operations Mission Directorates participate in the SBIR STTR Programs and provide research and technology (R&T) thrusts and their priority annually. Currently, the thrusts in Aeronautics Research are listed as aviation safety and security, vehicle systems, airspace systems, and aeronautics test technology. The Exploration

systems thrusts include Moon Initiative technology support, power, propulsion, and biological sciences. Earth science, solar system exploration, telescopes, sensors and detectors, helioscience, and spacecraft technologies thrusts are identified in the Science Mission Directorate. For Space Operations the current R&T thrusts are communications and operations.

The annual solicitations are managed by the SBIR STTR staff and are coordinated through the Headquarters mission directorate representatives (MDRs). Each center has technology element managers (TEMs) also known as topic managers. The TEMs are responsible for recommending specific topics and subtopics that will be developed for solicitation, with NASA Headquarters giving final approval. The topics are invariably chosen on the basis of technology needs/requirements for NASA missions and programs.

The TEMs and SBIR STTR staff review the submitted proposals and recommend the proposals deemed most relevant to the solicitation bid for technical and commercial reviews. Personnel having knowledge in the subject matter conduct these reviews at NASA centers. The evaluation criteria for Phase 1 and 2 proposals is based on a 50% score for scientific/technical merit and feasibility; a 25% score for experience, qualifications, and facilities; and a 25% score for effective-

ness of the proposed work plan. In addition to this, consideration is given to commercial potential and feasibility for commercializing for Phase 1 proposals. For Phase 2, commercial potential and feasibility are considered critical. This area is judged on the basis of commercial potential of the technology, commercial intent of the offeror, and the capability of the offeror to realize commercialization. All of the proposals that score 85% or more qualify for funding. NASA centers and/or TEMs rank these proposals using criteria that include value to NASA, reasonable chance of success, and probability that the company can successfully commercialize technology (Phase 3).

The priority of the selected proposals for possible funding is finalized by Headquarters mission directorates. Input to this priority is provided by the TEMs and NASA field centers. The Headquarters SBIR STTR official, in consultation with the MDRs, does the final selection.

3. IDENTIFICATION AND UTILIZATION OF SUCCESSFUL INNOVATIONS

As shown in Fig. 1, at the Johnson Space Center (JSC) the contracting officer (CO) informs the SBIR STTR management about the completion of the contracted work. The contracting officer's technical representative (COTR) then completes a new technology report (NTR). An NTR is required by the CO to close the contract. No further action is undertaken if new technology has not been disclosed. On the other hand, if new technology resulted, further reviews are conducted to identify possible NASA applications and promote the initiation of a Phase 3 contract with NASA. The small business is expected to follow the commercialization plan documented to NASA in the Phase 2 proposal.

NASA performs extensive research to identify success stories (SSs) for the SBIR STTR Program. These are researched in cooperation with the small businesses that have developed new software and/or hardware technology. As mentioned earlier, the COTR, NASA Small Business Technology Infusion Manager (STIM), and the SBIR STTR management identify opportunities within NASA programs and projects to use these

technology products. When an opportunity is found, a Phase 3 contract is initiated. More than \$11.5 million contracts have been initiated at JSC within the past 4 years. SBIR STTR technologies have been used in space shuttle, International Space Station (ISS), and Mission Control Center

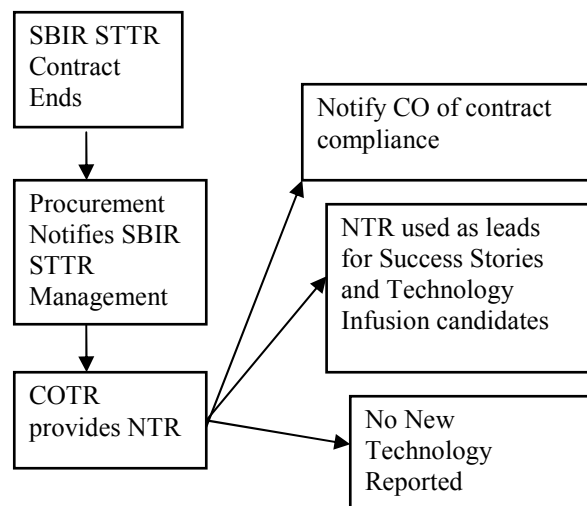


Fig. 1: JSC SBIR STTR invention disclosures process.

and JSC laboratory hardware and software. Several innovations are presently under consideration for Phase 3 at JSC.

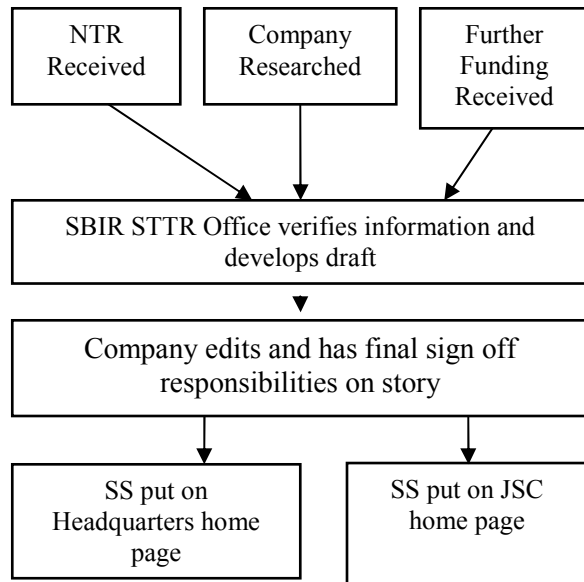


Fig. 2: Success story process.

4. JSC SBIR STTR SUCCESS STORY EXAMPLES

DisplayTech Inc., Long Mont, Colo., has developed and produced a revolutionary liquid-crystal color display providing workstation resolution on a display less than 1 inch across. The firm has filed four patent applications for this technology (Fig. 3).

The prototype head-mounted display system is a key element in obtaining the Department of Commerce Advanced Technology Program Award to develop low-cost, display mass manufacturing capability, and the Advanced Research Projects Agency SBIR award was given for the development of advanced image-producing electronics for display systems.

Markets applicable to this technology are miniature display, medical diagnostics, projectors, teleoperation systems, and engineering design. The firm partnered with Miyota Co., Ltd. in Nagano, Japan, for high-volume production in December 1998 to ensure success in the long term. Further partnerships have been created since, including a global network of distributors in Japan, Taiwan, and Europe. Among the firm's

SS is based on the progress of the small business in marketing the technology for commercial and space program use (Fig. 2). The number of jobs created, contracts received, patents received, patents licensed, and sales of products made are considered in evaluating the success of the business. In addition, the long-term business strategy and health are also considered. On the basis of these data, an SS description is developed by NASA and given to the particular business for review. After the review and approval of the small business, the SS is included in the Headquarters and JSC SBIR STTR SS Web locations. These locations are available to general public. The SSs are updated as new data become available. NASA also periodically reviews SSs to ensure currency of information. Obviously, some stories are removed to reflect the status of the business.

key customers are Kodak, Olympus, JVC, Hitachi, Konica-Minolta, Kyocera, HP, Sony, and others. The firm has sold over 16 million electronic viewfinder displays based on the NASA-funded technology.

Within NASA DisplayTech technology applications include extravehicular activity (EVA) high-information content, low-power, helmet-mounted display. For military and industrial applications, this technology replaces cathode ray tubes in high-cost head-and helmet-mounted displays.

Cybernet Systems Corporation, Ann Arbor, Mich., has developed a force feedback hand controller device that performs three main functions: (1) a 6-degree-of-freedom (DOF) controller (position and orientation of the hand) for controlling devices—mainly an advanced joystick or flight-yoke for the whole hand; (2) a force-reflecting hand controller to reflect input forces to a person's hand and arm; and (3) a dexterous master to reflect forces to a person's five fingers.



LightView™
Personal View Microdisplays



LightCaster®
Projection Microdisplays

Fig. 3: DisplayTech products.

The firm has created a force-feedback technology and developed several products and prototypes that demonstrated its commercial viability in consumer product markets. In March 1999, the firm's Haptic Systems Division was merged

into Immersion Corporation. Immersion has successfully marketed Cybernet's force-feedback technology (Fig. 4), and currently licenses it to companies such as Logitech, Microsoft, Thrustmaster, and CH Products.



Fig.4: Cybernet force-feedback hand controller.

This technology has been used by Immersion, the licensor of haptic feedback technology, and ALPS Electric Co., Ltd., one of the world's largest electronic components manufacturers with \$4.6 billion in annual consolidated revenue. These firms announced on April 22, 2002, a long-term automotive licensing agreement. This agreement builds on the cooperative efforts with Immersion to develop the BMW 7 Series iDrive Controller and reinforces the ALPS strategy to support the growing automotive telematics market and emerging x-by-wire technology. Immersion and BMW worked together to develop the iDrive system. It features a single control dial mounted on the center console. The driver slides the dial to choose between multiple control menus displayed on an in-dash liquid crystal diode screen. The driver rotates the dial to move through lists and pushes the dial axially to select a list item. The iDrive controller allows the driver to have instant and total control of every comfort element in the car, from the on-board navigation system to the air conditioner to the mobile telephone. Immersion and ALPS began working together in 2000 to incorporate haptic technology into the new BMW 7 Series car.

Cybernet developed a number of DOF and 3-DOF products that were sold in small units to various companies, including Lawrence Livermore National Lab, Ford, McDonnell Douglas, Wright Patterson Air Force Base, University of Delaware, Case Western Reserve, BMW, Federal Aviation Administration, INCO Limited, DISAM Escuela, High Techsplanation, Sandia National Labs, S.A. Sodetek, University of Nevada, and Battelle—all based on the work of these two contracts.

Immersion Corporation has obtained over 140 patents in tactile feedback technology, which is also known as haptics or the science of touch. The patent number for this technology is U.S. Patent 5,629,594-Force Feedback System.

Rapid Imaging Software, Albuquerque, N.M., developed the LandForm VisualFlight harnessing the power of a geographic information system (GIS) and the speed of a flight simulator, accessible from any Windows application (Fig. 5).

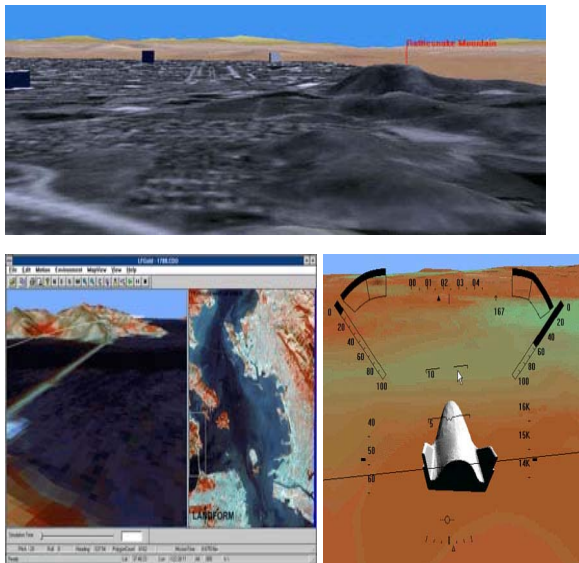


Fig.5: Rapid Imaging software displays.

One of the objectives was to put a scientific visualization program on a PC, making it easier for a lot more people to own and use such a program. The Advanced Flight Visualization Toolkit (VisualFlight) project continues developing a suite of virtual-reality immersive telepresence software tools that combines real-time flight simulation abilities with the data density of a GIS.

This technology is used for virtual-reality training of crews, analysis of flight test data, and as an on-board immersive situation display. It is also finding application as a virtual cockpit, and in the teleoperation of remotely piloted vehicles. People in airliners or flying general aviation aircraft are going to derive the benefits of this technology for years to come.

The technology fuses real-time three-dimensional displays of terrain with digital maps, satellite data, vehicles, flight paths, and waypoints incorporating a simplified user interface. This unique and innovative approach builds upon recent software technology research and development from Rapid Imaging Software. VisualFlight permits users to construct and deploy their own immersive multidimensional display applications on Windows-based computer platforms.

The firm's VisualFlight system was used to fly the NASA X-38 on its latest test flight. The flight vehicle was piloted by Astronaut Ken Ham using LandForm VisualFlight system as his digital cockpit window.

VisualFlight is sold as a development kit starting with five run-time licenses. Users who wish to distribute more applications using LandForm VisualFlight technology can purchase additional run-time licenses as needed. The LandForm V/O Video Overlay plug-in for LandForm C3 or Flight Vision is available for the Matrox Corona board only.

Cullimore & Ring (C&R) Technologies, Inc., Littleton, Colo., developed SINDA/FLUINT, a comprehensive finite-difference, lumped parameter tool to analyze complex thermal and fluid systems. SINDA/FLUINT saves time and money by making the design process faster and easier, letting the customers gain a better understanding of their complex system. The consumers control what is important and how to get the answer to their design performance questions using this efficient approach. The code is completely extensible, allowing users to choose the features, accuracy and approximation levels, and outputs. Users can also add their own customizations as needed to handle unique design tasks or to automate repetitive tasks (Fig. 6).

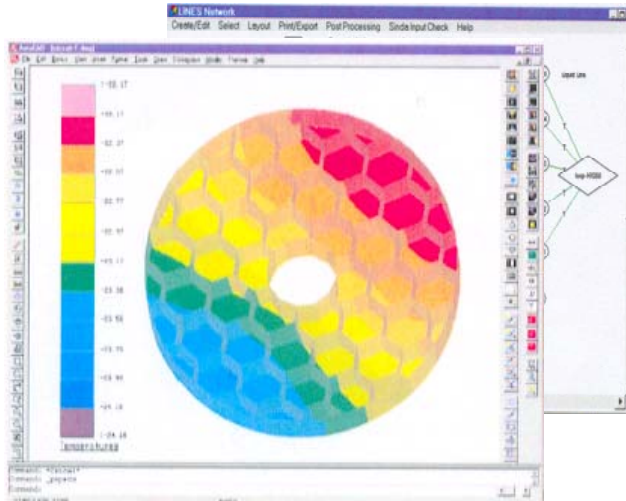


Fig.6: C&R displays.

C&R's numerous clients span diverse industries such as electronics packing, aerospace, automobile and aircraft engine cooling, air conditioning, fuel lubrication and hydraulic systems, spacecraft and launch vehicle thermal control, propulsion and environmental control, power generation systems, oil and gas pipeline and distribution systems, process design and control, and furnaces and kilns.

The NASA standard tool for thermohydraulic analysis, SINDA/FLUINT, includes thermodynamic and hydrodynamic solutions specifically targeted at the growing demand for the design and analysis of liquid propulsion systems, spacecraft and launch vehicle thermal, propulsion, and environmental control design. Other science and design applications include alternative energy systems and energy conservation design; automobile and aircraft engines; cooling, fuel, lubrication, climate control, and hydraulic systems; heating, venting, and air conditioning and fire protection systems; oil and gas pipeline; distribution; and steam injection systems.

With more than 4,000 users in 30 countries, applications for SINDA/FLUINT include the pharmaceutical, petrochemical, biomedical, electronics, and energy industries. The system has simulated nuclear reactors, windshield wipers, and human windpipes. SINDA/FLUINT simulates the transient liquid/vapor flows within air-conditioning systems, helping the automotive industry to meet standards for fuel-efficient, low-

emission cars. The system was the basis of General Motor's E-Thermal vehicle-level thermal management software, which is being deployed globally.

Environmental Robotics, Inc. (ERI), Albuquerque, N.M., has developed a family of novel synthetic muscle systems with robotic sensing and actuation capabilities for NASA space robotics and EVA applications. ERI is a world leader in distributed biomimetic nanosensors and nano-actuators, bio-mimetic biomedical products for human health, artificial muscles, and science kits and more. Two families of ionic polymeric artificial muscles have been developed: one a bending, flexing, deforming type with sensing and actuation capabilities and one of a fibrous electrochemical contractile type with over 100% strain and strength and power density comparable to mammalian muscles. ERI owns many U.S.-issued patents to support its product development activities.

Synthetic muscle systems with robotic sensing and soft actuation capabilities can also be used for terrestrial actuators, sensors, and transducers applications due to their unique performance. To bring technology of chemically activated polymers, in particular fibrous ionic polymers, to the attention of researchers, high school students, college students, engineers, and scientists, ERI has developed a low-cost Contractile Polymeric Artificial Muscle Science Kit (Fig. 7). To bring technology of electroactive polymers, in particular ionic polymer metal composites, to the attention of similar groups as listed above, ERI has developed a low-cost Artificial Muscle Science Kit.

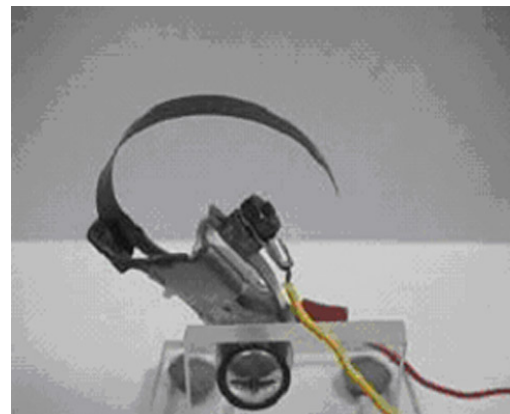


Fig.7: ERI Artificial Muscle Science Kit.

Developments for NASA include a family of novel synthetic muscle systems with robotic sensing and actuation capabilities, for primarily NASA space robotics and EVA applications, and any distributed nanosensing and nanoactuation government applications. Possible applications include NASA space robotics, autonomous ex-

travehicular actuation and sensing capabilities, and space robotic automation; as an example, a dust-wiping application in connection with solar cells and optical windows used in space robotics and landing missions.

5. JSC SBIR STTR SPACE APPLICATIONS EXAMPLES

Umpqua Research developed the microbial check valve (MCV) iodine-dispensing system for the space shuttle orbiter, introduced in 1979 to purify astronaut drinking water under NASA contract. In 1989, NASA awarded Umpqua a new contract for the development of a system that would overcome the limitations of the original MCV system and allow continuous, controlled release of iodine over a lengthy period for applications to the ISS and future long-duration spacecraft. That contract produced the regenerable biocide delivery unit, which was demonstrated in 1993 and is being considered as the baseline water purification system for the ISS.

NASA sought the help of Invocon, Inc., in 1979 to develop wireless sensor technology that monitors and measures various environmental and structural parameters inside the Aquarius underwater research facility, the ISS, and the space shuttle to maintain these as safe, healthy living and research habitats for personnel while keeping costs low. The resulting sensor system has flown and operated successfully on numerous space shuttle missions, and further use is being investigated for monitoring CO₂ concentrations on board the ISS in the crew sleeping quarters and in regions of reduced airflow.

Aspen Aerogels has developed a multifunction, multilayer aerogel composite for exploration suits and rovers. Another Aspen product is Spaceloft, an inexpensive, flexible blanket that incorporates a thin layer of aerogel embedded directly into the fabric. Spaceloft is hydrophobic and breathable. It is also three times more effective than the best commercially available clothing insulation. Recently, NASA JSC used Spaceloft to construct mittens as a precursor to space gloves for Mars exploration.

Lynntech successfully developed an advanced portable ion analyzer for water. Based on the results, the phase separator performed successfully in the flight tests performed. In the mesofluidic system that the phase separator is designed to operate in, the typical fluid flow rate is approximately 250 $\mu\text{L}/\text{min}$. In the tests, no failure in phase separation was detected for any flow rate less than 630 $\mu\text{L}/\text{min}$, or approximately 2.5 times the nominal flow rate of the device. Additionally, during a typical operation the gas flow rate in the inlet stream will likely be much lower than the liquid flow rate. In the configurations where the phase separation was incomplete during this flight test, the gas flow rate was typically as high as or higher than the liquid flow rate. This condition is less likely to be met in the ion analyzer system that the separator was designed for. Lastly, the degree of failure detected for higher flow rates was quite small. In every case tested, more than 99% of the inlet gas was removed from the outlet stream and, in most cases, a considerably higher percentage was removed. Therefore, this device may be used at higher flow rates in other applications where the requirements for gas removal are less strict than in ion chromatography. The overall results were highly beneficial for the project on the whole, and confirmed that the passive, small-footprint, mesofluidic phase separator design operates successfully in a microgravity environment at relevant flow rates.

Orbitec is developing a high-temperature, direct energy processing technique to produce oxygen from lunar regolith via carbonaceous high-temperature reduction. The utility in this new innovative technique overcomes problematic issues that were inherent in traditional high-temperature processing methods employing crucible-type containment vessels and hot-walled (i.e.,

resistance or inductive) furnaces. This new carbo-thermal process for the reduction of oxides in the regolith will provide NASA with a manageable, practical, and efficient technique for extracting a high percentage of oxygen from indigenous lunar resources for life support and propellant applications.

Orbitec successfully developed three-dimensional simulations of LADR [the LoTEC Active Door Recharger] and MERLIN [the Microgravity Experiment Research Locker Incubator]. The MERLIN Training System was developed under NASA SBIR Phase 3 contract in 2004 and the payload is scheduled for a shuttle flight. The shuttle MERLIN contains 21 animated procedures and three detailed models (Merlin, LADR, Express Rack), and is composed of over 300 separate animations with a file of 8.1 Megabytes size. This type of automated and intuitive procedure will be necessary for displaying integrated vehicle health monitoring status and to minimize the crew time needed for training for operations prior to and during missions.

TDA Research has developed a lightweight, freeze-tolerant radiator for an extravehicular mobility unit with the objective of reducing EVA consumables. For NASA, this radiator will reduce the cost of EVAs for the ISS by reducing the amounts of equipment and materials that have to be lifted to outer space. It also promises a reduction in the volume of equipment carried on the astronaut's back and a reduction in the battery power consumption. TDA has received Phase 3 funding for the freeze-tolerant radiator

with great potential for being a lightweight system with reduced expendables.

Tenxsys's innovation allows data and information to be remotely accessible across a broad range of devices including desktop PCs, PDAs, and Web-enabled cell phones. The system can be configured to provide automated alerts to relevant personnel when certain parameters fall outside of the expected range. The innovation integrates various types of sensor outputs. The data thus captured are reformatted and transmitted wirelessly/via satellite connectivity, and are presented to Web-based architecture users. Tenxsys distributed operations software for wireless handheld computers has supported the ISS under a Phase 3 contract.

A Tietronix innovation—TieFlow—increases the productivity of businesses by improving process cycle times in the areas of product design and development, purchase orders, expense reports, benefits enrollment, budgeting, hiring, and sales. This software can also handle claims processing, loan application and processing, health care administration, contract management, and advertising agency traffic. The processes can be captured in a graphical manner and enforced together with rules pertaining to assignments that need to be performed. NASA JSC is currently using the software for worldwide participation of authorized users in the Mission Operations Directorate and the Flight Director's Office. At the Flight Director's Office, TieFlow allows personnel to electronically submit and review changes to the flight rules carried out during a mission.

6. JSC SBIR STTR TECHNOLOGIES IN THE SPACE TECHNOLOGY HALL OF FAME

In 2004 two technologies developed under JSC Program were inducted in the Space Technology Hall of Fame. One of these is the LadarVision 4000 – Alcon (Fig. 8) originally developed by Autonomous Technologies.

Laser-assisted in-situ keratomileusis or LASIK is the most widely performed surgical procedure for vision correction. It uses a laser and an eye-

tracking device to reshape the cornea and is based on technology used to assist spacecraft in delicate docking maneuvers. The SBIR-developed technology enables LASIK to provide unmatched precision for the laser vision correction surgery. As a consequence of the success of LASIK surgery, fewer people now need eyeglasses or contact lenses.



Fig.8: 2004 Inductee LadarVision 4000 – Alcon.

The other 2004 inductee is the MedStar Monitoring System (Fig. 9) developed by Cybernet Evolved from research funded by NASA, the National Institute of Mental Health, and the Defense Advanced Research Projects Agency. This research resulted in a miniature physiological monitoring device capable of collecting and analyzing a multitude of signals in real time, which also is used to monitor astronauts on the ISS.



Fig. 9: The MedStar Monitoring System.

The cost of caring for the chronically ill continues to grow, and in-home care shows significant patient health improvements through

closer in-home monitoring. This innovation allows health care professionals to remotely monitor patients, promising worldwide improvement in health care.

Two technologies were inducted in 2005. One of these is the Nano Ceramic Sterilization Filter by Argonide Corporation (Fig. 10). This technology is based on NanoCeram alumina fibers, only 2 nanometers in diameter, which can be produced in multi-kilo quantities. The fibers are highly electropositive in water and attract and retain electronegative particles, such as virus, bacteria, mammalian cells (osteoblasts), endotoxins and macromolecules such as DNA and RNA.



Fig. 10: 2005 Inductee NanoCeram.

Key applications for this technology are chromatography; filtration of DNA, RNA, and endotoxins; sterilization of pharmaceuticals and medical serums; production of potable water; medical and dental offices applications; and as a collector for biological warfare detectors. In October 2002, the firm's new point of use Microbiological Filters received a major Environmental Protection Agency (EPA) grant for removing arsenic from drinking water to meet the new 10- $\mu\text{g}/\text{L}$ standard. NanoCeram fibers, owing to their high surface area, are capable of removing trace toxic metals from water. The EPA award funds the development of a household filter capable of removing arsenic from drinking water to satisfy the new 10 micrograms per liter specification. The unique set of properties exhibited by a newly identified family of oxide fibers is its ultra-small, 2-nanometer diameter with an aspect ratio from 20 to 100. NanoCeram fibers deliver substantial increased strength, support, and

insulation to metals, plastics, polymer-matrix and bio-materials.

The other 2005 inductee is the Triangle R&D Corporation/Outlast Technologies, Inc.-developed spacesuit glove liner with enhanced thermal properties for improved comfort (Fig. 11). The technology is based on micro-encapsulated phase change materials (MPCM) as a new thermal management system for fibers and fabrics. MPCM can be as much as four times more effective than systems that use trapped air for insulation.



Fig. 11: 2005 Inductee Outlast liners.

Boston Harbour, LLC of New York City has partnered with Outlast Technologies, Inc. of Boulder, Colo., to launch a complete line of men's and women's casual outerwear, using Outlast liners with revolutionary Adaptive Comfort technology. Under the brand PROSHIELD "Smart Apparel" consumers can experience all-day comfort powered by Outlast's patented phase-change fabric technology. This technology is also used in EvenTemp Bedding by Wamsutta. Marketed under the trade name Outlast Temperature Regulation and your Own Comfort Zone, this technology is covered by multiple U.S., European, and Japanese patents.

In 2007 the MCV, developed by Umpqua Research, was inducted into the Space Technology Hall of Fame (Fig. 12). The MCV system was originally developed for NASA to provide advanced water purification for the space shuttle and eventually the ISS. This technology eliminates bacteria and viruses in contaminated water using patented ion exchange resin feature that removes virtually all-residual iodine from treated water and is the core of the water purification systems now deployed in rural areas and developing countries.



Fig.12: 2007 Inductee MCV.

7. CONCLUSIONS

The SBIR STTR Programs provide opportunities for small, high-technology companies and research institutions to participate in government-sponsored research and technology efforts [1]. In this paper, examples of technologies funded by the SBIR STTR Program through JSC that have made important contributions to NASA programs and projects and have achieved commercial success are presented. Many other NASA

SBIR STTR technology success stories appear under success stories at the www.sbir.nasa.gov site. An example of the SBIR technology used for space shuttle return-to-flight after the *Columbia* accident is the wireless sensors from Invocon, for the impact detection system in the wing leading edge of the shuttle. These wireless sensors are also used for vehicle health monitoring and microgravity instrumentation on

the ISS. For a commercial application, Alcon Laboratories developed an eye-tracking device for LASIK surgery that tracks eye movements at four times the established safety margin. This technology was developed with SBIR funds

from JSC for the use of laser tracking technology for spacecraft rendezvous and docking application.

8. ACKNOWLEDGEMENTS AND NOTE

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This paper is not intended to endorse any products or businesses. Many SBIR STTR businesses have achieved great success through JSC contracts. The businesses discussed in this paper are a few examples of these.

9. REFERENCES

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Abstract Submissions for 58th IAC

For

Category C Technology

Session E 5.1 Innovating Through Technology Spin-in and Spin-off

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The accomplishments of the NASA Johnson Space Center (JSC) Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) Program will be presented. The SBIR Program was established by U.S. Congress in 1982 to provide increased opportunities for small businesses to participate in research and development (R&D), to increase employment, and to improve U.S. competitiveness. The program's specific objectives are to stimulate U.S. technological innovation, use small businesses to meet federal research and development needs, increase private-sector commercialization of innovations derived from federal R&D, and foster and encourage participation by socially disadvantaged businesses. Legislation enacted in 2000 extended and strengthened the SBIR program and increased its emphasis on pursuing commercial applications of SBIR project results. The STTR Program awards contracts to small business concerns for cooperative research and development with a non-profit research institution, such as a university. The goal of the U. S. Congress in establishing the STTR program is to facilitate the transfer of technology developed by an RI through the entrepreneurship of a small business. The small business and its partnering institution are required to sign an agreement on how intellectual property will be shared between them. Modeled after the SBIR Program with the same basic requirements and phased funding structure described above, STTR is nevertheless a separate activity and is separately funded.

Technologies that have resulted from JSC SBIR STTR Program with world-wide commercial impact will be discussed. These technologies include: - A device for regenerating iodinated resin beds to extend their useful life for water disinfection resulting in a simple, low cost, non-capital intensive alternative to chlorination based water purification systems. Known as the microbial check valve (MCV), this technology provides a means of preventing back contamination of a drinking water supply by microorganisms. This technology eliminates bacteria and viruses in contaminated water using patented ion exchange resin feature that removes virtually all residual iodine from treated water. - Laser-Assisted In Situ Keratomileusis or LASIK is the most widely performed surgical procedure for vision corrections in the recent past. It uses a laser and eye-tracking device to reshape the cornea and is based on technology used to assist spacecraft in delicate docking maneuvers. SBIR technology enables LASIK to provide unmatched precision. -A miniature physiological monitoring device capable of collecting and analyzing a multitude of signals in real time with capability to transmit this medical data from remote locations to medical centers for diagnosis and medical intervention. - A Micro-encapsulated Phase Change Materials (MPCM) as a new thermal management system for fibers and fabrics giving rise to new line of garments and thermal enhancing environments. - A highly electropositive material that attract and retain electronegative particles in water, such as virus, bacteria, mammalian cells (osteoblasts), endotoxins and macromolecules such as DNA and RNA.