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A STRUCTURE FOR CAPTURING QUANTITATIVE BENEFITS FROM THE TRANSFER OF SPACE AND AERONAUTICS TECHNOLOGY

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ABSTRACT

Since the beginning of the space program there has been a steady stream of public benefit around the world from the applications of technologies developed for space and aeronautics to problems on Earth. There have been numerous studies and approaches developed for measuring these benefits, but none have been broadly accepted or consistently adopted. Many anecdotal examples have provided snapshots of quantitative benefits but there exists no structured method of systematically collecting and evaluating benefits. NASA has developed an approach to begin systematic collection of quantitative benefits from the transfer of space and aeronautics technology. This approach identifies a small number of quantitative measures that capture predominant categories of benefits. In some cases the benefits can be fully attributed to the original NASA technology, although in most cases the application of NASA technology is a *contributing factor* in the innovation that has ultimately generated the benefits. The definition of these quantitative measures was shaped by analysis of the last several years of technology transfer successes published in NASA's annual *Spinoff* document. NASA has begun to implement the collection and validation of these measures in the process of writing and documenting future *Spinoff* stories, and is retrospectively collecting information from previously published *Spinoff* stories. This paper presents the structure NASA has developed and summarizes the quantitative benefits that have been identified thus far.

INTRODUCTION

NASA develops technology to create space and aeronautics capabilities needed to execute its mission; these technologies and applications have also been applied to solving problems and enhancing capabilities here on Earth. There have been many studies and approaches developed for generalizing the measure of these earth-based benefits of space technology; methodologies include equations, algorithms, theories, and surveys. Many studies used economic multipliers based on input/output models from generalized data not traceable to specific examples. Some of the challenges and limitations of these historical methods revolve around the size of the data set, the scope of the benefits being recognized, and even the reliability of the projections and modeling done without solid, verifiable data.

While limited in utility or scope, many of the past studies are still useful today to illustrate particular aspects of the economic benefit of space research and technology development. Often these studies have produced an economic or productivity impact model or the development of a numeric ratio expressing the effect of economic benefit from investments in NASA. As summarized in Table 1, previous studies have indicated discounted rates of return from 33%[1] to 43%[2], and include ratios from around 7[3] up to a

Table 1. Over the past several decades, there have been many efforts to quantify the benefits of NASA's technology transfer efforts. This table summarizes several of the most significant, their methodologies, and their limitations.

Date	Study	Methodology	Quantitative Findings	Limitations
1971	Economic Impact of Stimulated Technological Activity," *Final Report, Midwest Research Institute, Contract NASW-2030*	• Macroeconomic projections	• Average 7:1 rate of economic return on each dollar invested in NASA • Discounted rate of return on NASA investments of approximately 33%	• Limited to ratios of R&D expenses to national economic gains
1976	"Quantifying the Benefits of the National Economy from Secondary Applications of NASA Technology," *Mathematica*[4]	• Case studies of four major NASA technology categories (cryogenics, gas turbines, integrated circuits, and NASTRAN computer system)	• $1B estimated benefit of NASA contribution to cryogenics • $5B estimated benefit of NASA contribution to integrated circuits • $111M estimated benefits of NASA contribution to gas turbines • $701M estimated benefit of NASTRAN	• Small data set, lacking comprehensive overview of full NASA technology transfer portfolio • Not sustainable • Dated • Restricted only to revenue generation • Forward-looking projections of future benefit
1976	Michael K. Evans, "The Economic Impact of NASA R&D Spending," *Chase Econometric Associates, Inc., Bala Cynwyd, Pennsylvania, Contract NASW-2741*	• Simulations and modeling	• Average 7:1 rate of economic return on each dollar invested in NASA • Historical rate of return from NASA R&D spending of 43%	• Focused solely on economic forecasting and projections using theoretical increases and decreases in NASA funding
1988	"Economic Impact and Technological Progress of NASA Research and Development Expenditures," *Midwest Research Institute, Kansas City, Missouri, for the National Academy of Public Administration*[5]	• Macroeconomic projections	• Average 9:1 rate of economic return on each dollar invested in NASA • Discounted rate of return on NASA investments ranging between 19 and 35%	• Limited to ratios of R&D expenses to national economic gains
1989	"An Exploration of Benefits from NASA 'Spinoff'," Richard L. Chapman, Loretta C. Lohman, and Marilyn J. Chapman[6]	• Examination of 259 published *Spinoff* stories • Telephone interviews and inquiries	• $21.3B NASA contributions to sales • $315.7M NASA contributions to cost savings • 325,000 jobs created/saved • $365M in tax receipts	• Data set restricted to NASA *Spinoff* companies • Restricted to revenue from sales and cost savings
1993	"The Nature and Extent of Benefits Reported in NASA 'Spinoff'," Richard L. Chapman, Marilyn J. Chapman, Mary F. Chapman, and Jody Briles[7]	• Examination of 353 published *Spinoff* stories • Telephone interviews and inquiries • Continuation of 1989 Chapman Report	• $32B NASA contribution to sales • $1B NASA contributions to cost savings	• Data set restricted to NASA *Spinoff* companies • Not repeated • Restricted to revenue generated and savings
1994	"The Economic Impact of the Space Program: A Macro and Industrial Perspective," prepared for Rockwell International by *The WEFA Group, Bala Cynwyd, Pennsylvania*[8]	• Economic modeling	• Estimated 380,000 NASA-generated jobs by 1997 • $153.5B in GDP generated by NASA-related activity by 2000	• Restricted to job growth • Restricted to human spaceflight and ISS
1997	"Space as an Investment in Economic Growth," Henry R. Herzfeld[9,10]	• Surveys • Telephone interviews and inquiries • Literature review • Case studies	• Over $1.5B in value added to 15 NASA life sciences partner firms	• Small dataset, restricted to 15 program-specific technologies • Difficulty collecting data, survey responses • Not repeated

23.4[i] multiplier effect depending on the study, its criteria, and its methodology. Another ratio often calculated in past studies is the number of jobs created as a result of investment in NASA. The

[i] Mathematica calculated the high measure in a study based on the benefits of a technology transfer program that infused little funding into the effort. It is therefore not an accurate measure of national cost/benefit effect of NASA R&D funding. It is, nonetheless, often used as such.

multiplier for jobs created as a result of every $1 million (2009 dollars) invested in NASA ranges from 7.8[11] to 19.4[12] over several studies conducted on this subject.

In spite of the lack of a consistent analytic framework, and an almost exclusive reliance on the capture of *economic* benefits, many of these studies have weathered years of criticism and analysis and still provide a useful foundation and context for understanding and communicating the benefits of NASA technology. While a common conclusion is that NASA's R&D yields tangible and economic benefit in addition to meeting NASA mission needs, to date, there has not been a defensible and generalizable mechanism for measuring quantitative benefits that proves sustainable over time. While most prior studies have focused on the study of economic benefits, there are other benefits such as lives saved and quality of life improvements that have not been taken into consideration. In addition, the lack of sustainability in approaches to gathering quantitative benefit data and the general desire to achieve sustainability was another observation made by many prior studies.[13]

Some of the prior efforts to quantify the benefits of space technology are summarized in graphic in Figure 1, based on data contained in Table 1. The benefits described by prior efforts are impressive, but collectively they represent individual efforts and not a systematic analytic approach. They use inconsistent assumptions and measures, and occur irregularly, sometimes with many years between studies.

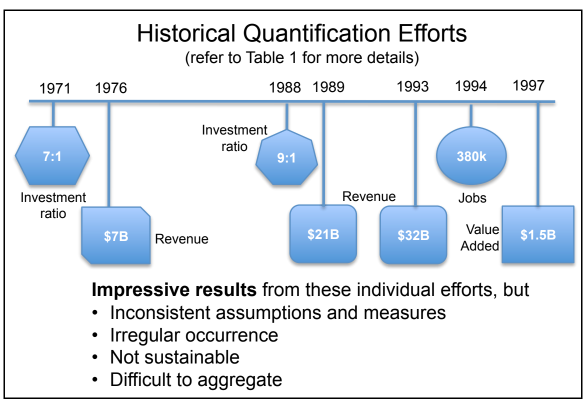

Figure 1 – While beneficial, past studies quantifying benefits have not provided consistent or sustainable data or analysis.

In Figure 1, the different shapes represent differing measures and assumptions and contain some of the key measures represented by the studies in those years – refer back to Table 1 for more details. One weakness of previous studies is that they do not suggest a mechanism for automatic capture of data—data capture is not built into the regular processes for doing business and thus requires unique funding and are therefore not easily sustainable over time, from a budgetary point of view. Finally, because of the differing assumptions and measures used, it is difficult to reliably aggregate the results of these different studies over the years to describe a more comprehensive picture of the benefits of NASA technology. In addition, many anecdotal examples, such as those that have been published since 1976 in NASA's annual *Spinoff* publication[14], have provided snapshots of quantitative benefits but there exists no structured method of systematically collecting and validating benefits.

QUANTIFICATION CATEGORIES

While the anecdotal evidence provides a broad overview of NASA's technology transfer activities, lacking is a structured and measurable quantification methodology of the benefits of these commercialized technologies. Just as the stories within the *Spinoff* publication have been categorized into subject categories (health and medicine, transportation, etc.), within these categories, there is room for further classification of the actual benefits, by identifying commonalities across the subject categories.

Each of the 187 technologies featured in *Spinoff* from 2007-2010 was examined in detail to extract any possible quantifiable measures of benefit and/or success, due in part or in full, to NASA's influence on the subject company's product or service. Examination of a critical mass of these benefits revealed emerging patterns and thus common areas of quantification became readily apparent.

This analysis[15] allowed NASA to identify a small number of quantitative measures that capture the predominant categories of benefits. In some cases the benefits can be *fully attributed* to the original NASA technology, although in most cases the application of NASA technology is a *contributing factor* in the innovation that ultimately generated the benefits. The five standard categories of quantifiable benefits and units of measure are summarized below.

- Jobs created, measured in number of jobs
- Revenue generated, measured in dollars
- Productivity and Efficiency Improvements, measured in dollars
- Lives Saved/Not Lost, measured in number of individuals
- Lives Improved, measured in number of individuals

NASA is beginning to implement the collection and validation of these measures as *Spinoff* stories are documented and written, and is also retrospectively beginning to collect information from previously published Spinoff stories.

This approach builds on previous studies and will begin to systematically and sustainably collect a standardized set of benefits that can be aggregated over time to understand and communicate the benefits to the public attributable to technology transferred from NASA. A diagram illustrating this concept is shown in Figure 2. The consistent shapes represent consistency in the benefit categories and assumptions used when collecting the data. The size of the boxes represents the magnitude of the technology transfer cases that are captured at different times.

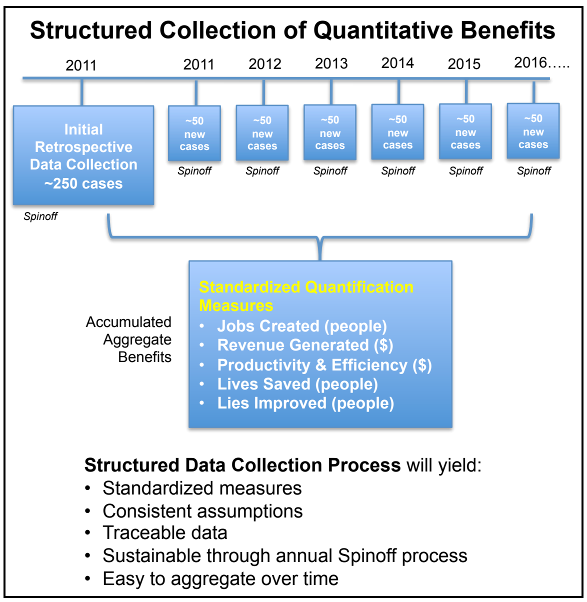

Figure 2 – The methodology developed by NASA for using structured data collection is consistent and sustainable, enabling aggregation of benefits data over time.

In FY2011, NASA conducted a retrospective survey of several years of companies whose technology was featured in *Spinoff* to build a solid base of quantified benefits in these standard categories. This analytic architecture will be consistently used to capture data in the future. Each smaller box in Figure 2 represents the spinoff stories documented each year – approximately 50 – used to collect quantitative data for each story in the standardized categories. The data is traceable to the source – the companies that actually commercialized the NASA technology – building confidence in the validity of the data and of the methodology. Because the categories are standardized and the collection method uses standard assumptions, the data collected over time is easy to aggregate to describe in broader terms the benefits to society from transfer of space technology for benefit of the public. The larger box that also shows the standard quantification measures represents this aggregation.

DATA COLLECTION

It is appropriate for data to come from the companies actively engaged in commercializing NASA technology, as they are in the best position to know the benefits. In gathering this data, issues arose that both complicated the current data collection and also informed how future data collection tools could be designed. While collectively these issues could present a problem, each has an implementable solution. The best solution in presenting this data in each instance, however, is to provide it within an appropriate context, acknowledging its scope and limitations.

1. Data Outliers

Although many traceable veins arose from an examination of this data (each company, for example, will likely have generated revenue from the sale of a spinoff product, which could be gathered and measured), it is important to note that there were unique and significant outliers in the types of measurable benefits produced by the companies featured in *Spinoff*.

A key area where there are benefits that do not neatly fit into any of these standard categories is environmental benefits. Reductions in use of fossil fuels, reductions in emissions of greenhouse gasses, reductions in carbon footprint, improvements in water quality, improvements of natural habitats and surroundings for different forms of life, and reductions in use of other natural resources can all be considered positive environmental impacts. However, identifying a simple common measure to represent the category of environmental benefits was elusive.

Therefore, within this framework, quantitative benefits from environmental spinoffs are limited to the five standard categories identified even though it is known that additional benefits exist. This does not reduce the significance of these benefits, but underscores the need to continue to collect the technology transfer benefits anecdotally in the *Spinoff* report. The collection of quantitative and measurable benefits should serve as a supplement to these stories.

2. Consistency of Data

Because the interviews conducted for the *Spinoff* articles were not previously designed with this benefit quantification in mind, most of the existing data are not consistent from company to company. The methods of capture, time components, frequency of capture, methods of measurement, and availability vary widely from story to story. Although some companies provided actual numerical pieces of data to be published in *Spinoff*, most plausible benefits had to be inferred, and the numbers provided spanned many different lengths of time periods as well as units of measure.

Future collection of this type of quantitative benefits data will require that NASA normalize it by having interviewers ask consistent questions and clarify any anomalies before publishing the data. This is being incorporated into the standard interview protocols conducted for future *Spinoff* article preparation.

3. Reliability of Data

In capturing the information for *Spinoff* articles, NASA must rely on both the integrity and the soundness of the record keeping of the companies that elect to provide this data. Because this is voluntary, there is no method to enforce the provision of this data. The companies provide NASA with the information voluntarily, and it is understood that the data represent their best estimates. One potential solution to this dilemma is to have the companies validate in writing their belief that all of the supplied information is true. This level of accountability may be enough to steer the information into being more accurate or trustworthy. Another potential avenue for increased data collection is to make reporting of benefits, both anticipated and actual, a requirement in NASA contracts and grants.

In addition, as a matter of practice, the technical personnel and technology transfer staff who currently provide approval and consent to publish each of the *Spinoff* stories are now also charged with doing a reasonableness assessment and confirming that this new reported information is reasonably accurate to the best of their knowledge.

Finally, any use of this data needs to be situated in the proper context, with NASA acknowledging that the Agency is not responsible for validating the accuracy of the reported data.

4. Data Capture

As mentioned above, there is no current authority for NASA to require the provision of data describing benefits as a result of technology transfer. A privately held company has no mandatory legal obligation to publish its financial and performance data, and the majority of companies engaged in technology transfer with NASA are privately held. Further, both multiple privacy laws and the Paperwork Reduction Act restrict gathering of data by the Federal government.

Nonetheless, there are several methods NASA could use to encourage companies to freely provide this data. First, the provision of data could be used as a requirement for publication in the high profile *Spinoff* report. Companies routinely report great benefit from the publicity and association with NASA from having been published in this annual report.

Another possible and recommended policy for gathering this data would be for NASA to write into its Small Business and Innovation Research (SBIR) contracts a requirement for companies to provide data on any commercial success resulting from the partnership as a requirement before the company is permitted to apply for another contract under this same program. One potential drawback of this method is that perhaps the most successful companies, those that are able to truly leverage the SBIR program to produce a commercial product, may not be then applying for more NASA SBIR contracts. Chances are, though, that these growing companies would still be willing to report on their success, if it is owed in part to NASA, but this approach would require NASA personnel to follow up.

The same approach to data gathering—writing a requirement into contracts/agreements—could be applied to other technology transfer mechanisms, such as licensing agreements or Space Act Agreements.

RETROSPECTIVE DATA COLLECTION

With little available data on quantitative benefits, NASA is seeking to expand the available data from historical *Spinoff* stories to supplement those that will be collected each year going forward using a consistent and sustainable methodology. To do this, NASA developed and is administering a survey based upon the standard benefit categories identified. This survey focuses on companies featured in *Spinoff* between 2003 and 2008 and was designed to easily, consistently, and accurately capture available data that falls into the benefit categories while also gathering other data that could have future use.

The National Technology Transfer Center (NTTC) has been administering the survey for NASA. The first step in this process is to contact the companies by telephone and explain the survey and its purpose. It is made clear at this time and later explicitly stated that participation is voluntary and any information gathered may, or may not, be published or otherwise used at NASA's discretion. Companies are cautioned to not provide personal information (e.g. the names of people hired), confidential information, or any proprietary information.

Next, once an appropriate contact has been established, the NTTC will send an electronic form that asks a series of questions, the first of which is to determine whether NASA's role in the development of the technology was primary or secondary (i.e. was the Agency an enabling factor, or was NASA more assistive in the development of the product?).

The additional survey questions seek to gather the quantifiable benefits data, and ask for the respondent to then clarify whether the numbers being provided are estimates or if the figures have been calculated. If calculated, the company is then asked to explain the calculation. The primary questions are as follows:

- Has the technology created jobs?
- Has the technology resulted in increased revenue?
- Has the technology resulted in the saving of dollars?
- Has the technology resulted in the saving of time?
- Has the technology saved lives?
- Has the technology enhanced/improved/extended lived?

The companies are also asked to describe any other quantifiable benefits, such as "green" impacts or other general impacts. They are than also asked to provide additional information that they find appropriate.

Results are still being gathered, and the data must be reviewed and analyzed before it is fully released, but of the 250 companies (representing 274 different technologies) that have been contacted to date, 103 have responded to date with quantification of benefits in one or more of these categories, representing a response rate of approximately 38%. This survey is still ongoing, and at its conclusion, the data will be further analyzed and published.

Initial results confirm the effectiveness of the proposed benefit categories, as multiple companies are able to report quantifiable data within these categories. While the percentage of stories for which quantifiable data is available following interviews with the companies is significantly below the expected rate, for several categories it is factor of five above the rate that has already been published in *Spinoff*. Therefore, it is clear that direct contact with companies through the use of surveys, when combined with the use of consistent category models, yields more comprehensive data.

The interim survey results are showing impressive results in terms of the quantifiable benefits that are being captured. Initial results – as summarized in the descriptions that follow with some illustrative examples – indicate that from this snapshot of *Spinoff* success stories over 9,200 jobs were created, over $1.2 billion in revenue has been generated, over $6 billion in cost avoidance from productivity and efficiency improvements, more than 12,000 lives saved, and more than 86 million lives have been improved.

SURVEY RESULTS

Jobs Created. Of the 250 companies polled, the 75 companies who provided data reported the creation of more than 9,200 jobs. An additional 19 companies reported that no jobs were created by the use of NASA technology. Some examples are provided below.

- Through SBIR contracts with Ames Research Center, Intelligent Automation Inc. (IAI), based in Rockville, Maryland, advanced specialized software the company had begun developing with U.S. Department of Defense funding. The agent-based infrastructure now allows NASA's Airspace Concept Evaluation System to explore ways of improving the utilization of the National Airspace System (NAS), providing flexible modeling of every part of the NAS down to individual planes, airports, control centers, and even weather. The software has been licensed to a number of aerospace and robotics customers and has even been used to model the behavior of crowds. IAI's SBIR-derived Cybele technology was instrumental in the formation of the company's ATM group that currently employs 20 people.
- A Space Act Agreement with Goddard Space Flight Center and West Virginia University enabled Aurora Flight Sciences Corporation, of Manassas, Virginia, to develop cost-effective composite manufacturing capabilities and open a facility in West Virginia. The company now employs 160 workers at the plant, tasked with crafting airframe components for the Global Hawk unmanned aerial vehicle (UAV) program. While one-third of the company's workforce focuses on Global Hawk production, the rest of the company

develops advanced UAV technologies that are redefining traditional approaches to unmanned aviation. Since the company's founding, Aurora's cutting-edge work has been supported with funding from NASA's Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs. Aurora now has 350 employees and has facilities in Mississippi and Massachusetts, in addition to its West Virginia and Virginia operations.

- Glenn Research Center awarded Small Business Innovation Research (SBIR) contracts to ManTech SRS Technologies, of Newport Beach, California, to develop thin film inflatable antennas for space communication. With additional funding, SRS modified the concepts for ground-based inflatable antennas. GATR (Ground Antenna Transmit and Receive) Technologies, of Huntsville, Alabama, licensed the technology and refined it to become the world's first inflatable antenna certified by the Federal Communications Commission. Capable of providing Internet access, voice over Internet protocol, e-mail, video teleconferencing, broadcast television, and other high-bandwidth communications, the systems have enabled communication during the wildfires in California, after Hurricane Katrina in Mississippi, and following the 2010 Haiti earthquake. Since its start in 2004, GATR has sold 60 ground-based inflatable antenna systems. In 2010 alone, the company's goal was to produce 50 more systems. With just under 20 employees, revenue has increased from $3 million in 2008 to $5.6 million in 2009. Most recently, *Inc.* magazine featured GATR on their list of the top 500 fastest growing entrepreneurial companies in the United States.

- Control and simulation software developed under Small Business Innovation Research (SBIR) contracts with Johnson Space Center is now providing user-friendly, optimized design and control of innovative robots used for military, agriculture, healthcare, and industrial applications. Created by Energid Technologies Corporation, of Cambridge, Massachusetts, the Actin toolkit provides for fluid robot motion, enhancing strength and accuracy while avoiding collisions and joint limits. Actin provides control capabilities for virtually any kind of robot, any joint type or tool type, and for any number of joints, degrees of freedom, and branches. In addition, the software provides powerful simulation capabilities, allowing developers to rapidly devise and test robot designs before the robot is built. Energid now has 20 employees and opened an office in India to promote Actin's capabilities in Asia.

- With SBIR awards from Kennedy Space Center, Sierra Lobo Inc. (SLI), based in Fremont, Ohio, developed the Cryo-Tracker Mass Gauging System (Cryo-Tracker MGS). The Cryo-Tracker MGS is a three-part system that integrates the use of software, electronics, and the "R&D 100" award-winning Cryo-Tracker probe. SLI is marketing the Cryo-Tracker MGS to companies that use and store cryogens, including medical organizations, metals processors, and semiconductor manufacturers, which use the Cryo-Tracker MGS to monitor mass, liquid levels, temperature, and pressure for stored liquid helium, hydrogen, nitrogen, or oxygen. SLI began with only 9 employees in 1993, and now has an ISO 9001:2008 registration and over 370 employees.

Revenue Generated. Of the 250 companies polled, 83 provided revenue figures attributable to NASA, with a total of over $1.2 billion. Ten companies reported no gains in revenue. Summaries of some of the responses are provided in the discussion below.

- In 2005, two physicians, former NASA astronauts, created LifeWings Partners LLC, in Memphis, Tennessee, and began using Crew Resource Management (CRM) techniques developed at Ames Research Center in the 1970s to help improve safety and efficiency at hospitals. According to the company, when hospitals follow the LifeWings training, they can see major improvements in a number of areas, including efficiency, employee satisfaction, operating room turnaround, patient advocacy, and overall patient outcomes. LifeWings has brought its CRM training to over 90 healthcare organizations, and annual sales have remained close to $3 million since 2007.

- Collier Research Corporation, of Hampton, Virginia, licensed software developed at Langley Research Center to reduce design weight through the use of composite materials. The first license of NASA-developed software, it has now been used in everything from designing next-generation cargo containers to airframes, rocket engines, ship hulls, and train bodies. The company now has sales of the NASA-derived software topping $4 million a year and has recently received several Small Business Innovation Research (SBIR) contracts to apply its software to nearly all aspects of the new MPCV crew capsule design.

- Aspen Aerogels, of Northborough, Massachusetts, worked with NASA through an SBIR contract with

Kennedy Space Center to develop a robust, flexible form of aerogel for cryogenic insulation for space shuttle launch applications. The company has since used the same manufacturing process developed under the SBIR award to expand its product offerings into the more commercial realms, making the naturally fragile aerogel available for the first time as a material that can be handled and installed just like standard insulation. This product currently produces an excess of $270 million in revenue per year.

Efficiency and Productivity Improvements. Of the 250 companies surveyed, 45 companies said that they experienced no efficiency improvements that could be expressed as dollars, while 46 did achieve cost avoidance totaling over $6.2 billion. Summaries of some of the responses are provided in the discussion below.

- The upturned ends now featured on many airplane wings are saving airlines billions of dollars in fuel costs. Called winglets, the drag-reducing technology was advanced through the research of Langley Research Center engineer Richard Whitcomb and through flight tests conducted at Dryden Flight Research Center. Seattle-based Aviation Partners Boeing—a partnership between Aviation Partners Inc., of Seattle, and The Boeing Company, of Chicago—manufactures Blended Winglets, a unique design featured on Boeing aircraft around the world. These winglets have saved more than 2 billion gallons of jet fuel to date, representing a cost-savings of more than $4 billion and a reduction of almost 21.5 million tons in carbon dioxide emissions.
- Deep Ocean Engineering (DOE) Inc., of San Leandro, California, received several SBIR awards from NASA to develop remotely operated vehicle (ROV) technologies with Ames Research Center. DOE engineers developed a concept for a versatile and robust locomotion methodology based on snake and worm morphologies. This "super snake" has the ability to transition seamlessly from one environment to another, such as land to water to burrowing into soft sediment. DOE ROVs are in use by U.S. armed forces, Hydro Quebec, and more than 40 universities and scientific organizations. The U.S. armed forces use the ROVs in security measures and intelligence gathering, and Hydro Quebec—Canada's largest electric utility and second largest corporation, which generates more than 95 percent of its production from hydroelectric facilities—uses a DOE ROV to inspect dams and hydroelectric apparatus for damage, saving an estimated $10 million in two seasons.
- Annapolis, Maryland-based designAmerica Inc., a small aerospace company specializing in the development and delivery of ground control systems for satellites and instrumentation, assisted Goddard Space Flight Center in the development of the ASIST software, a real-time command and control system for spacecraft development, integration, and operations. It was designed to be fully functional across a broad spectrum of satellites and instrumentation, while also being user friendly. The company now has rights to commercial use of the program and is offering it to government and industry satellite designers. The demonstrated cost savings is well over $3 million for the ground system element.

Lives Saved. Of the 250 companies surveyed, 53 said that their technology had not saved any lives, while 20 companies reported that their technologies had indeed saved lives, over 12,000 of them. Summaries of some of the responses are provided in the discussion below.

- Small Business Innovation Research (SBIR) contracts with Langley Research Center helped BRS Aerospace, of Saint Paul, Minnesota, to develop technology that has saved 265 lives to date. The company's whole aircraft parachute systems deploy in less than 1 second, thanks to solid rocket motors, and are capable of arresting the descent of a small aircraft, lowering it safely to the ground. BRS has sold more than 30,000 systems worldwide, and the technology is now standard equipment on many of the world's top-selling small aircraft. Parachutes for larger airplanes are in the works.
- To keep life rafts holding astronauts and frogmen from capsizing from the downdraft of rescue helicopters after Apollo-era splashdown landings, engineers at NASA's Johnson Space Center designed and patented a self-righting life raft capable of resisting tipping in choppy seas and fierce winds. Givens Marine Survival Co. Inc., of Tiverton, Rhode Island, patented this invention and now manufactures and markets the rescue rafts—under the name Givens Buoy Life Raft—in a variety of sizes and models for everything from sailboats to larger ocean-going vessels. To date, Givens has sold several thousand of the ballasted, inflatable life rafts, and this space-age technology is credited with saving the lives of over 450 sailors.

Lives Improved. Of the 250 companies polled, 18 reported improving or enhancing lives, while 53 again said that this category did not apply to their spinoff product. Of the companies who did respond in the affirmative, the total lives improved or enhanced was over 86 million. Summaries of some of the responses are provided in the discussion below.

- Johnson Space Center, Henry Ford Hospital in Detroit, and Houston-based Wyle Laboratories collaborated on NASA's Advanced Diagnostic Ultrasound in Microgravity (ADUM) experiment, which developed revolutionary medical ultrasound diagnostic techniques for long-distance use. Mediphan, a Canadian company with U.S. operations in Springfield, New Jersey, drew on NASA expertise to create frame-grabber and data archiving technology that enables ultrasound users with minimal training to send diagnostic-quality ultrasound images and video to medical professionals via the Internet in near real time—allowing patients as varied as professional athletes, Olympians, and mountain climbers to receive medical attention as soon as it is needed. Over 950 ultrasound examinations have been performed on patients so far.
- Medtronic Inc., of Minneapolis, Minnesota, licensed Langley Research Center's Soluble Imide for use as insulation on thin metal wires connected to its implantable cardiac resynchronization therapy devices, for patients experiencing heart failure. The devices resynchronize the contractions of the heart's ventricles by sending tiny electrical impulses to the heart muscle, helping the heart pump blood throughout the body more efficiently. Each year, 6 million patients benefit from Medtronic's technology.

SPINOFF DOCUMENTATION PROCESS

As NASA continues to gather the stories for the annual *Spinoff* report, the writers will now routinely survey the companies being interviewed and collect quantifiable data within the standard categories. This will provide the Agency with an ongoing record of measurable successes in technology transfer. As years pass, and the volume of more accurate data continues to increase, it is possible that broader analyses could be conducted from the aggregate of this information related to the number of jobs and revenue, for example, that secondary uses of NASA technology have provided.

While NASA will not be able to validate all of the information being gathered, it can and will conduct reasonableness assessments. If a company is reporting having hired a large number of people, the field center personnel who work with that company will have an idea of whether that number is accurate from having worked with the companies as during the technology transfer process. The technology transfer staff at each of the centers will therefore be asked to review collected data and sign off before any material is published.

The information gathered in the future will be written into the *Spinoff* articles and will supplement the existing qualitative data, not replace it. While this new data will be a valuable supplement to the traditional anecdotal reporting of spinoff successes, the stories will continue to tell the grainy, interesting, and unexpected personal stories of NASA's contributions to the Nation's well-being.

CONCLUSION

There is ample evidence from multiple studies and data collection efforts that NASA's investments in space technology yield important benefits in terms of economic return, revenue generation, and creation of jobs. What is lacking is a consistent and sustainable method of regularly collecting data in consistent standardized categories that can be aggregated over time to collectively – although not exhaustively – describe the benefits of space technology.

This paper describes the methodology that NASA is pursuing to implement an approach that will enable regular data collection as part of standard processes for collecting an documenting technology transfer success stories for the annual *Spinoff* publication. Built on an effort to retrospectively gather this data from the last several years of *Spinoff* companies, a solid foundation is being established upon which to build a robust database of quantifiable benefits from space technology in the future. Such a collection of data that is traceable to its source – the companies that commercialized the technology – will be a useful tool in better understanding and communicating to stakeholders and the public, the often dramatic and certainly sustained value of investments in NASA technology.

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