

ANALYSIS AND
RECOMMENDATIONS TO STRENGTHEN
COMMERCIALIZATION OUTCOMES OF NASA-FUNDED RESEARCH GRANTS
AND COOPERATIVE AGREEMENTS AT COLLEGES AND UNIVERSITIES AND
NON-PROFIT ORGANIZATIONS

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Executive Summary

This report summarized an effort to investigate the factors associated with the creation of new technologies and patented inventions from NASA Glenn research grants and cooperative agreements with colleges, universities and non-profit organizations over the period 1995 through 2004. We used this information in statistical models to predict the count of new technologies created and patents issued from the agreements as a function of a variety of different factors.

By identifying the factors positively and negatively associated with the creation of new technologies and patented inventions from NASA Glenn research grants and cooperative agreements with universities and non-profit organizations, we can identify “best practices” and recommendations that could be adopted to increase the level of new technology production from NASA research grants and cooperative agreements with these institutions. The recommendations from the report focus on how to maximize these outcomes from Ohio institutions. However, our underlying data, of necessity, reflects NASA’s interactions with institutions throughout the country.

The study had fifteen findings:

1. An average of 18.8 new technologies and 7.3 new patents are created annually as a result of NASA Glenn funded research grants and cooperative agreements with colleges and universities and non-profit organizations.
2. The average amount of NASA Glenn funding to colleges and universities and non-profit organizations needed to create a new technology is \$3,967,810.24 and to generate a patented invention is \$9,665,178.79.
3. The number of new technologies created increases with the size of NASA Glenn funded research grants at colleges, universities and non-profit organizations.
4. The longer the term of the research grant or cooperative between NASA Glenn and colleges and universities and non-profit organizations, the more new technologies the recipients create.
5. The more recent the agreement, the lower the number of new technologies created and new patents issue.
6. The further the recipient of the research grant or cooperative agreements is located from NASA Glenn, the lower the rate of new technology creation.
7. New patent generation is higher for advanced development projects than for other types of projects.
8. Non-profit organizations have a higher rate of new technology creation than educational institutions.
9. Cooperative agreements generate more new technologies than research grants.
10. Non-profit organizations generate more new technologies from basic research projects than colleges and universities and fewer new technologies from applied research projects than colleges and universities.
11. The greater the geographical distance of the recipient from NASA Glenn, the more new technologies are created from applied research projects.
12. Location of the recipient in Northeast Ohio has a negative effect on the amount of new technology created and a new patent issued from applied research and

- exploratory development projects, and has a positive effect on the number of new patents issued from basic research projects.
13. Recipients located in Ohio produce fewer new patents from their cooperative agreements than recipients located outside of Ohio.
 14. There are no statistically significant effects of the industrial infrastructure of the metropolitan statistical area in which the recipient was located on the rate of new technology creation or patent generation.
 15. Academic institution quality increases the number of patents issued by academic institution recipients of NASA Glenn research grants and cooperative agreements for basic research projects, but decreases it for applied research and exploratory development projects.

Based on these findings, the report made the following recommendations for increasing the rate of new technology creation and new patent production from Nasa Glenn research grants and cooperative agreements with colleges and universities and non-profit organizations:

1. Treat colleges, universities and non-profit organizations as important extenders of the new technology production activity of NASA Glenn.
2. Recognize that the research and development cost of producing new technologies and patented inventions from NASA-Glenn funded research grants and cooperative agreements at colleges, universities, and non-profit organizations is going to be the same as that of producing all new technologies and patented inventions at these institutions, and that increasing the total amount of funding at these institutions is going to be necessary to generate significant increases in the amount of technology creation from NASA-Glenn funded projects at these institutions.
3. Consider advocating that NASA policy on grants and cooperative agreements that favor longer initial periods (e.g., five years) and allows for options for renewal.
4. Assess whether the goal of NASA Glenn is to increase the production of new technologies, new patents or both when designing NASA-Glenn's technology commercialization strategy; the factors that increase the number of new technologies are not the same as the factors that increase the numbers of new patents issued.
5. Implement annual new technology reporting requirements for recipient institutions, perhaps connected with the award of continued funding, to ensure the new technologies are reported on at least an interim basis throughout the progress of the grant or cooperative agreement.
6. Develop policies to encourage institutions in close proximity to NASA Glenn to engage in focused collaborative efforts with other institutions to take advantage of geographic proximity effects on technology commercialization.
7. Increase collaboration between non-profit institutions and area colleges and universities to maximize the strengths of each type of institution in the creation of new technologies under grants and cooperative agreements and basic research through advanced development projects.

8. Consider developing and implementing a pilot project supported by regional resources in which a non-profit NASA intermediary collaborates with universities specifically on the commercialization of NASA Glenn-sponsored research and technology in which non-profit organization recipients of NASA Glenn research grants and cooperative agreements conduct basic research projects and college and university recipients of NASA Glenn research grants and cooperative agreements conduct applied research and exploratory development projects.
9. Consider implementing focused consideration of basic research projects for progression to more advanced stages of development with the same investigator and institution.
10. Emphasize cooperative agreements as a funding vehicle to enhance technology creation outcomes.
11. Consider matching types of projects and types of agreements to the location of the recipient to maximize the advantages at generating technology from NASA Glenn funded projects of institutions in different locations.
12. Evaluate projects from organizations without concern for the industrial infrastructure in the area surrounding the recipient institution.
13. Consider developing a policy of matching the type of project to college and university research quality to maximize the advantages of different institutions in generating technology from NASA Glenn funded projects.

Introduction

Policy makers are increasingly interested in the role that Federal laboratories play in the creation of new technologies. In particular, they are interested in understanding how to link the technology production activities of Federal laboratories with those of private companies, universities, and non-profit organizations. Over the past 25 years, federal law and policy have systematically been applied to increase the contribution of federal laboratories to the production of new technologies that can be commercialized by the private sector. The Stevenson-Wydler Technology Innovation Act of 1980, the Federal Technology Transfer Act of 1986, the National Competitiveness Technology Transfer Act of 1989, the Defense, Conversion, Reinvestment and Transition Assistance Act of 1992 among other laws, have sought to enhance the creation and transfer of new technologies from Federal government laboratories.

In addition to the thrust of efforts to increase the direct creation and transfer of technology from Federal laboratories, policy makers sought to increase the involvement of federal laboratories in commercial innovation by facilitating the creation of (and transfer to the private sector of) new technologies at universities and non-profit organizations from federally-funded projects. From efforts, such as the Bayh-Dole Act of 1980, which gave universities the rights to inventions from federally funded research on university campuses, to Federally Funded Research and Development Centers operated by universities, to Cooperative Research and Development Acts, the federal government has sought to use the indirect channel of funding of colleges, universities and non-profit organizations to increase levels of technology production and transfer from federal laboratories.

One of the major participants in the direct and indirect technology transfer efforts has been the National Aeronautics and Space Administration (NASA), which is one of the leading federal agencies producing new technology. Since the Space Act of 1958, technology transfer has been an important mission of NASA. While NASA's program has recently been refocused on inward technology infusion rather than on outward technology transfer, the agency remains an important producer of commercial technology, and has a federal mandate to transfer technology to the private sector.

NASA operates ten research centers. One of them, The NASA Glenn Research Center, is located in Cleveland, Ohio. While focusing on aeropropulsion, power systems for aerospace and environmental information systems, the center is also NASA's lead research center in turbomachinery, propulsion systems, and microgravity research. NASA research centers conduct significant amounts of research in house, but also funds research grants and cooperative agreements with outside researchers to conduct research and development on topics important to NASA.

Although the primary goal of research grants and cooperative agreements funded by NASA Glenn at colleges, universities and non-profit organizations is the investigation of specific research questions, an important secondary goal is the creation of new technology. New technology creation offers many benefits, including the ability to spur

economic development by bringing new knowledge into commercial practice. Therefore, many stakeholders of NASA Glenn would like to know how to maximize the commercial outcomes of NASA Glenn research grants and cooperative agreements at colleges, universities and non-profit organizations.

This report summarizes an effort to investigate the factors associated with the creation of new technologies and patented inventions from NASA Glenn research grants and cooperative agreements with colleges, universities and non-profit organizations over the period 1995 through 2004. By identifying the factors positively and negatively associated with the creation of new technologies and patented inventions from NASA Glenn research grants and cooperative agreements with universities and non-profit organizations, we can identify “best practices” and recommendations that could be adopted to increase the level of new technology production from NASA research grants and cooperative agreements with these institutions. We will focus our recommendations on how to maximize these outcomes from Ohio institutions. However, our underlying data will of necessity reflect NASA’s interactions with institutions throughout the country.

The Scope of the Study

The goal of this study was to examine the factors associated with the creation of new technologies and patented inventions from NASA Glenn’s research grants and cooperative agreements with colleges, universities and non-profit organizations. Consequently, only these agreements with these entities were examined.¹ Readers should note that the factors discussed in this study might not explain the creation of new technologies and patented inventions from NASA Glenn’s agreements with small and large firms, and no inference should be made to the production of new technologies and patented inventions from agreements with those entities from this report.

Because the study examines NASA Glenn agreements in which the primary purpose is to achieve “a public goal authorized by Federal law” rather than direct benefits to NASA Glenn, it examines only research grants and cooperative agreements. It does not govern procurement agreements, which govern transactions for things which are “mission critical” for NASA, or are conducted primarily for NASA’s own purposes. In addition, the study excludes educational and training grants and research grants classified by the Federal Procurement Office as “educational services” because the production of new technology and issued patents is not a goal of those projects.

This study focuses on the period 1995-2004 due to data limitations. NASA Glenn records on research grants, cooperative agreements and new technology creation are not comprehensive prior to 1995. Therefore, the period from the passage of the Bayh-Dole Act in 1980 through 1994 cannot be examined here.

¹ Non-profit organizations are organizations that qualify for tax exemption under section 501 of the Internal Revenue Code of 1954.

The study seeks to explain two outcomes: new technology creation and the issuance of patents. Because of the relatively small number of new technologies created over the past decade (188) and an even smaller number of patented inventions (73), it is not possible to identify factors associated with the creation of new products, production processes, license agreements, and start-up companies. The number of new technologies created from NASA Glenn agreements with colleges and universities and non-profit organizations that result in new products, processes, licenses and start-up companies is too low to permit statistical analysis of the factors associated with these outcomes.

This latter finding is, in and of itself, significant in terms of overall goals of enhancing regional economic development through the generation of new technology by university-funded research, since it is in the creation of new products, processes, licenses and companies that economic impact is generated. While our primary focus in this study is on the factors which seem to help to foster the creation of new technologies from NASA GRC-sponsored research at universities and non-profit organizations, we recognize that new technology creation is just the beginning of a chain of events which ultimately lead to economic impact. Thus, we will also offer some recommendations which we believe will strengthen the chances that new technologies, once developed, will be utilized to generate economic value.

The Study Methodology

Sample

We obtained information from NASA Glenn on the population of all research grants and cooperative agreements made with colleges and universities and non-profit organizations between 1995 and 2004. We then excluded all research grants classified as “educational services” by the Federal Procurement Office. The resulting sample consisted of 1945 research grants and cooperative agreements.

Sources of Data

From several NASA databases we obtained information on the magnitude of the funding from each agreement, the principal investigators, the titles of the projects, the institutions receiving funding, the number of new technologies created from the agreements, the procurement code for the type of projects, and the dates that the agreements began and ended.

We gathered additional information from the US Patent and Trademark Office on whether US patents had been issued for inventions resulting from the funded projects.

We gathered several additional pieces of information on the recipient organization from a variety of sources. We identified whether the recipient was a college/university, high school, or non-profit organization. We also measured the geographic distance from the recipient institution to NASA Glenn. For colleges and universities, we measured the academic quality of the recipient institution using the National Research Council’s rankings of graduate programs in science and engineering. We also measured the faculty

rank, department and organizational role of the principal investigator for those agreements made with colleges and universities.

We obtained several pieces of information on the projects. We used information from NASA Glenn to determine whether a grant, cooperative agreement, or other agreement governed the project. We also used information from NASA Glenn to determine whether the project was a basic research, applied research and development, or educational service agreement. Finally, we measured the time horizon of the agreement between NASA Glenn and the recipient.

We gathered information from a variety of sources on the industrial composition of the location in which the recipient organization was found. We measured the manufacturing intensity, technological production intensity, reliance of businesses in that location on a science and engineering workforce, and the business employment in the area of the recipient organization.

Measures

New Technologies: We measured new technologies as all new technologies reported to NASA by non-profit organization and academic institution recipients of NASA grants and cooperative agreements through their use of NASA form 1609. According to federal law, “nonprofit organizations and colleges and universities [receiving funds from NASA] must disclose all subject inventions to NASA. Subject invention as used in NASA Funding Agreements with other than large businesses means any invention or discovery which is or may be patentable and is conceived or first actually reduced to practice in the performance of work under a NASA Funding Agreements. Subject inventions include any new process, machine, manufacture, or composition of matter, including software, and improvements to, or new applications of, existing processes, machines, manufactures, and compositions of matter, including software.”²

Patents: We measured patents as all issued patents reported in the United States Government Patent and Trademark Office database that had an inventor who was a principal investigator on the research grant or cooperative agreement as NASA Glenn had funded and whose patent abstract covered the same subject matter as the abstract for the research grant or cooperative agreement funded by NASA Glenn.

Research Grants: In this study, a research grant is defined as a grant “used to accomplish a NASA objective through stimulating or supporting the acquisition of knowledge or understanding of the subject or phenomena under study, or attempting to determine and exploit the potential of scientific discoveries or improvements in technology, materials, processes, methods, devices, or techniques and advance the state of the art. [With research grants, the recipient bears] prime responsibility for the conduct of research, and exercises judgment and original thought toward attaining the scientific goals within broad parameters of the research areas proposed and the resources provided.... Grants are distinguished from cooperative agreements in that substantial

² NASA New Technology Summary Report http://entre.nasa.gov/forms/NASA_NTSR_form.doc

involvement is not expected between NASA and the recipient when carrying out the activity.”³

Cooperative Agreements: In this study, a cooperative agreement is defined as a the “legal instrument reflecting a relationship between NASA and a recipient whenever the principal purpose is the transfer of anything of value to the recipient to accomplish a public purpose of support or stimulation authorized by Federal statute, and substantial involvement is anticipated between NASA and the recipient during performance of the contemplated activity Characteristics inherent in a cooperative agreement include those that apply to a grant, plus the following: Substantial NASA involvement in and contribution to the technical aspects of the effort are necessary for its accomplishment. This could involve an active NASA role in collaborative relations, access to a NASA site or equipment, or sharing NASA facilities and personnel The project, conducted as proposed, would not be possible without extensive NASA-recipient technical collaboration.”⁴

Amount of Funding: We measured the amount of funding as the dollar value of the research grant or cooperative agreement as recorded by NASA’s procurement database.

Basic research: We measured basic research as all research grants and cooperative agreements classified as basic research by the Federal Procurement Data Center.⁵

Applied research and exploratory development: We measured applied research and exploratory development as all research grants and cooperative agreements classified as applied research and exploratory development by the Federal Procurement Data Center.⁶

Advanced development: We measured advanced development as all research grants and cooperative agreements classified as advanced development by the Federal Procurement Data Center.⁷

College or University: We measured a college or university as an institution of higher learning, following the NASA procurement definition. According to this definition, colleges and universities are distinct from non-profit organizations, large businesses, small businesses, and high schools.

Non-Profit Organization: We measured non-profit organizations as organizations that qualify for tax exemption under section 501 of the Internal Revenue Code of 1954, following the NASA procurement definition. According to this definition, non-profit organizations are distinct from colleges and universities, high schools, large businesses, and small businesses.

³ NASA Grants and Cooperative Agreements Handbook <http://ec.msfc.nasa.gov/hq/granta.html#126012>

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⁵ Federal Procurement Data Center Classification http://www.fpdc.gov/fpdc/fpdc_home.htm

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Geographic Distance from NASA Glenn: We measured geographic distance from NASA Glenn as the driving distance from NASA Glenn's main entrance as calculated by Mapquest.com.

Location in Northeast Ohio: We measured location in Northeast Ohio if the NASA Glenn records indicated that the recipient's address was located in the "consolidated metropolitan statistical area" (CMSA) that includes the primary metropolitan areas around Cleveland/Lorain and Akron, which the US Department of Census defines as Northeast Ohio.

Location in Ohio: We measured location in Ohio if the NASA Glenn records indicated that the recipient's address was located in the state of Ohio.

Case Western Reserve University: We measured Case Western Reserve University as the recipient of the research grant or cooperative agreement if the NASA Glenn records indicated that "CWRU," "Case," or "Case Western Reserve University" was the recipient of the research grant or cooperative agreement.

Cleveland State University: We measured Cleveland State University as the recipient of the research grant or cooperative agreement if the NASA records indicated that "CSU," "Cleveland State," or "Cleveland State University" was the recipient of the research grant or cooperative agreement. To ensure that the designation "CSU" did not represent Central State University, but represented Cleveland State University, we used two techniques. First, where the abbreviation CSU existed in the database, we sought to determine if the full university name was listed under the same agreement number in another part of the NASA database. If another part of the database indicated "Cleveland State University" for that agreement number we treated the CSU abbreviation as representing "Cleveland State University. If another part of the database indicated "Central State University" under the same agreement number, we treated the CSU abbreviation as representing that university. If the database alone could not distinguish the two universities from the abbreviation, we conducted a Google search on the name of the principal investigator. If the principal investigator was employed by Cleveland State University at the time that the grant or cooperative agreement was awarded, we treated the abbreviation as representing Cleveland State University. If the recipient was employed by Central State University at the time that the grantor cooperative agreement was awarded, we treated the abbreviation as representing Central State University.

Ohio Aerospace Institute. We measured Ohio Aerospace Institute as the recipient of the research grant or cooperative agreement if the NASA records indicated that "OAI" or "Ohio Aerospace Institute" was the recipient of the research grant or cooperative agreement.

Year of Agreement: We measured the year of the agreement as the year in which the research grant or cooperative agreement was initiated according the NASA Glenn procurement office records.

Term of Agreement: We measured the term of the agreement as the number of years from the start date of the agreement to the end date of the agreement.

University Quality: We measured university quality as the average of the National Research Council rankings across all doctoral programs in the biological sciences, physical sciences, and engineering.

Manufacturing Intensity: We measured manufacturing intensity as the share of total sales in the metropolitan statistical area where the recipient of the research grant or cooperative agreement was located that the US Department of Census' County Business Patterns defines as by manufacturing establishments.

Technological Production Intensity: We measured technological production intensity as the number of patents in the metropolitan statistical area where the recipient of the research grant or cooperative agreement is located divided by the population of the metropolitan statistical area. We used data from the US Patent and Trademark Office to measure the number of patents in the metropolitan statistical area and data from the US Department of Census to measure population in the metropolitan statistical area.

Business Intensity: We measured business intensity as the number of business establishments per capita in the metropolitan statistical area where the recipient of the research grant or cooperative agreement was located using data from the US Department of Census.

Scientific and Engineering Workforce Intensity: We measured the scientific and engineering workforce intensity in the metropolitan area where the recipient of the research grant or cooperative agreement was located using data from the US Department of Labor, Bureau of Labor Statistics' occupational employment statistics. We calculated scientific and engineering work force intensity as the number of architecture and engineering occupations, plus computer and mathematical science occupations, plus life, physical and social science occupations, plus healthcare practitioner and technical occupations divided by total occupations.

Statistical Analysis

We used this information in statistical models⁸ to predict the count of new technologies created and patents issued from the agreements as a function of a variety of different factors. The sections below summarize the results of the statistical analysis. In addition, for factors for which there was a statistically significant effect in the models run, means and other descriptive information is provided in tables. For those factors which had no statistically significant effects in the overall models, this information is not provided in the tables to avoid confusion as to the effects of different factors.

Some Examples of New Technologies and Patents Created

⁸ The specific statistical model used was a negative binomial model.

Non-profit organizations and colleges and universities that receive funding from NASA Glenn research grants and cooperative agreements are required to disclose any and all new technologies created as a result of these NASA agreements. Examples of the new technologies created by non-profits and colleges and universities under NASA agreements include:

- **Automated serial-sectioning of metallic and other opaque materials for three-dimensional reconstruction of micron scale structures**, a technology that “allows one to collect a series of cross-sections with separation distances between the cross-sections as small as $1\mu\text{m}$ for a variety of materials for example solders and aluminum alloys. Using these cross-sections the three-dimensional structure can then be reconstructed. This approach allows the evaluation of metallic microstructures in three dimensions.”
- **Microfluidic Controller And Microvalve**, “a method for synthesizing permanently linked monodisperse paramagnetic chains by both covalently linking surface-functionalized polystyrenes particles and physically linking electrostatically stabilized paramagnetic emulsion droplets.”
- **Magnetic Bearing Position & Current Stiffness Data Acquisition System**, an “automated display, data acquisition and reduction software ... to measure the position and current stiffness of a magnetic bearing versus speed, eccentricity and temperature.”

Not all new technologies created result in patented inventions. The number of new patented inventions can be larger or smaller than the number of new technologies created. The number can be smaller because only some new technologies created are worthy of patent application. Some new technologies are not novel, non-obvious or valuable and so do not meet the criteria of patentability. Other invention disclosures are already covered by existing patents and so are not patentable. Still other new technologies created are not sufficiently valuable to justify the cost and effort of patent application.

The number of new patents can be larger than the number of new technologies created because a given new technology might be protected by more than one patent because different patents are needed to protect different dimensions of the invention. Some examples of new technologies created by non-profits and colleges and universities with funds under NASA research grants and cooperative agreements for which more than one patent was awarded include:

- **Nano-crystalline porous tin oxide film for carbon monoxide sensing**, a sensor that “rapidly detects reducing gases, such as carbon monoxide, or hydrocarbons and organic vapors ...and therefore provide[s] good detection systems for detection of trace amounts of pollutants such as toxic and flammable gases in homes, industrial settings, and hospitals.”
- **Method and apparatus for reducing high-cycle fatigue and suppressing noise in rotating machinery**, “a stator apparatus for mounting upstream of an intake to a rotating machine which blows

pressurized air, or other media, from discharge orifices at a pressure and velocity to minimize velocity defects or turbulence in the wake of the stator prior to the plane of rotation of a rotating member of the machine.”

- **Method of providing ceramic article with wear resistant coating**, “An improved method ... to provide a ceramic article with a protective coating which resists mechanical wear at elevated temperatures up to 500 degrees C. and higher”

The Number of New Technologies and Patents Created

Finding #1: An average of 18.8 new technologies and 7.3 new patents are created annually as a result of NASA Glenn funded research grants and cooperative agreements with colleges and universities and non-profit organizations.

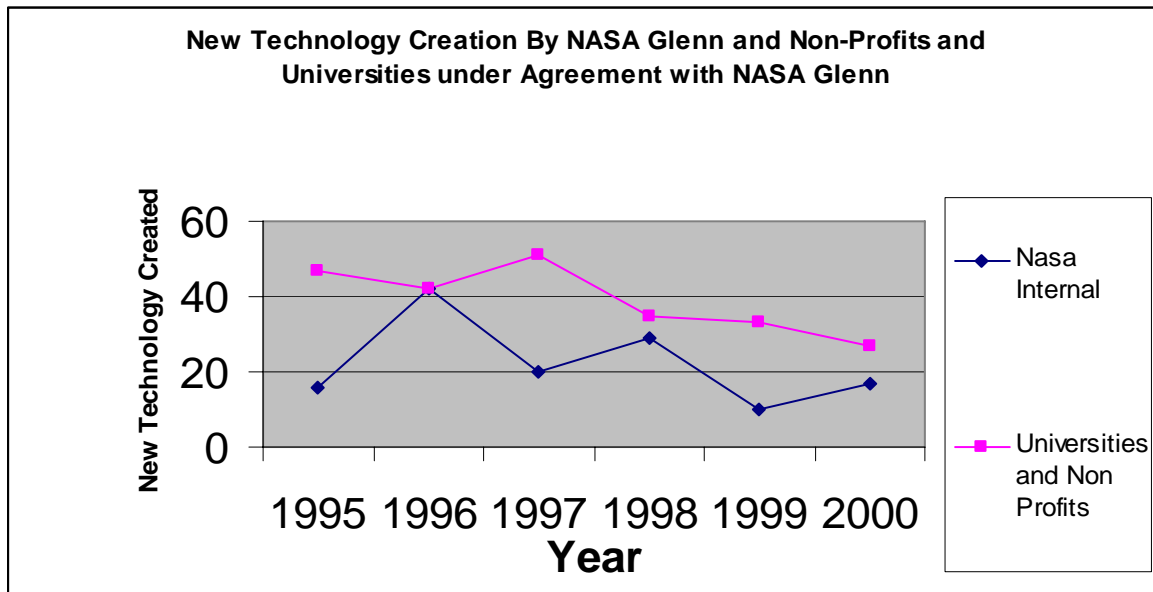
The rate of new technology creation out of NASA Glenn funded research grants and cooperative agreements with colleges and universities and non-profit organizations is an important topic for policy makers. If many new technologies can be created as a result of NASA-funded projects at these institutions, then NASA Glenn funding might provide an important mechanism for leveraging new technology creation in a region. Researchers generally believe that the creation of new technologies by universities and non-profit organizations from government funded research projects are rare events because only a small portion of projects funded at colleges and universities and non-profit organizations focus on topics that are sufficiently commercial to generate new technologies.

The results of this study confirm this observation. Between 1995 and 2004, NASA Glenn research grants and cooperative agreements with colleges and universities and non-profit organizations generated 188 invention and new technology disclosures (including software) and 73 patents. This is a rate of 18.8 new technologies and 7.3 patents created per year. Expressed per NASA agreement, this means one new technology was created for every 10.35 agreements and one new patent was created for every 26.64 agreements over the 1995 to 2004 period.

During the period between 1995 and 2000, when comparable data is available on new technologies created within NASA Glenn and by universities and non-profits with NASA research grants and cooperative agreements, the external entities increased the new technology creation rate by an additional 57 percent over the rate produced by NASA Glenn directly through in-house research. This confirms our premise that the research funded by NASA GRC at universities and non-profits represents a very important and significant portion of all new technologies created with NASA funding. Moreover, the potential for economic development resulting from NASA-sponsored new technologies is seriously incomplete without including the impact of NASA-sponsored research at universities and not-for profits.

Recommendation:

The amount of new technology creation from NASA Glenn through funding of research at universities and non-profit organizations significantly increases the amount of overall new technology creation over that onsite at NASA Glenn. To accurately understand the role of NASA Glenn research in influencing economic development, evaluators should consider the role of indirect channels of technology creation, such as that through the funding of colleges, universities and non-profit organizations, and should measure those indirect channels in making evaluation of the economic development impact of NASA Glenn.



The Cost of Creating New Technologies

Finding #2: The average amount of NASA Glenn funding to colleges and universities and non-profit organizations needed to create a new technology is \$3,967,810.24 and to generate a patented invention is \$9,665,178.79.

The cost of generating new technologies from NASA funded projects is an important policy issue. Researchers generally believe that the creation of new technologies by universities and non-profit organizations from government funded research projects is costly. In many of the areas in which NASA Glenn funds research, the equipment needed is expensive and the amount of staff necessary to conduct research is large. In the United States and other countries, the cost of each invention disclosure by federal laboratories and colleges and universities falls in the several million dollar range. One reason why is that the type of research and development conducted by colleges and universities and non-profit organizations is very far from commercial stage and is highly

uncertain. The high failure rate of research efforts leads to small numbers of successful outcomes. Moreover, the time horizon for these projects tends to be quite long, resulting in relatively few commercial outcomes per time period worked.

The analysis summarized in this report supports this argument. From 1995-2004, NASA Glenn spent \$709,427,274.50 on research grants and cooperative agreements at colleges and universities and non-profit organizations. On average, each invention disclosure generated from this funding effort cost \$3,773,549.33 and each patent cost \$9,718,181.84.

By way of comparison, The Association of University Technology Managers (AUTM) reports that for the period 1995-2002, each invention disclosure at US and Canadian universities cost \$2,188,576.30 in research and development dollars and each patent cost \$8,673,220.70.⁹ Over the same period as AUTM reports its data, at colleges and universities that received NASA-Glenn research grants and cooperative agreements, the research and development cost of each invention disclosure was \$3,473,766.10 and each patent was \$6,773,844.

Although exact comparison is difficult to make because the data from the Association of University Technology Managers includes Canadian institutions, it appears that the research and development cost of patents created from NASA Glenn-funded research grants and cooperative agreements is *less* than that for all projects at US and Canadian academic institutions; whereas the research and development cost of invention disclosures created from NASA Glenn funded research grants and cooperative agreements is *more* than that for all projects at US and Canadian institutions.

Two factors might account for these differences. First, the Association of University Technology Managers data includes information from Canadian colleges and universities and Canadian institutions might behave in systematically different ways from American colleges and universities. Second, NASA Glenn funds very different projects from the average project funded at American colleges and universities. In particular, research projects at American colleges and universities are more likely to be biomedical than is the case for NASA Glenn-funded projects. It is possible that biomedical projects result in more invention disclosures and fewer patents than aerospace projects.

Another important point of comparison is between NASA internal technology production from NASA funding at universities, colleges and non-profits. In 2001 and 2002, the research and development cost of producing an invention disclosure at NASA was \$4,205,000.¹⁰ Over that same two year period, the production of an invention disclosure from NASA research grants and cooperative agreements at non-profit organizations and colleges and universities was \$5,317,521.40. The greater cost of invention disclosures at non-profit organizations might be due to costs associated with research infrastructure (labs, facilities, and the need to create new ones). However, we do not have the data to ascertain the reasons for this greater cost.

⁹ Association of University Technology Managers Survey http://www.autm.net/index_ie.html

¹⁰ National Academy of Public Administration. 2004. Technology Transfer: Bringing Innovation to NASA and the Nation, Mimeo.

Recommendation:

The R&D cost of NASA Glenn funded research at colleges, universities and non-profit organizations is not trivial, but in line with that of all funded research at these institutions. This finding suggests that policy makers need not be concerned about problems with the technology creation productivity of NASA Glenn-funded research at colleges, universities and non-profit organizations, but, at the same time, have realistic expectations about the amount of new technology that can be created per dollar of funding. It is our recommendation that NASA Glenn, through appropriate channels within NASA, explore a policy of obtaining additional budgetary resources to allocate to research grants and cooperative agreements in the interest of increasing the number of new technologies created by recipients, thereby enhancing the economic development impact of NASA Glenn..

The Effect of the Amount of Funding Per Agreement on New Technology Creation

Finding #3: The number of new technologies created increases with the size of NASA Glenn funded research grants at colleges, universities and non-profit organizations.

Researchers generally believe that economies of scale exist in new technology creation. Because a portion of all research funding pays for administration and overhead, the amount that can be devoted to new technology creation increases with the amount of funding.

The size of the research grants and cooperative agreements made by NASA Glenn has a statistically significant positive effect on the number of new technologies created by colleges and universities and nonprofit organizations receiving that funding. Each additional \$1,000,000 of funding increases the number of new technologies created by the recipient by 22 percent. There was, however, no statistically significant effect of the amount of funding provided by NASA Glenn on the number of patented inventions created by the recipient institutions, perhaps because the number of patented inventions is small.

We also examined whether the effect of the amount of funding per agreement had any statistically significant effect on the number of new technologies created or new patents issued in interaction with any other factors. We found that, for cooperative agreements, the effect of increased funding on the number of new technologies created was ***negative***. Each additional \$1,000,000 of funding for cooperative agreements reduced the number of new technologies by 2 percent. This result indicates that the overall positive effect of funding on the number of new technologies created exists only for research grants, not for cooperative agreements.

However, it is important to note that for cooperative agreements close cooperation between the government and the external researcher is expected and research is carried out largely on site at NASA Glenn. Therefore, the likelihood is high that new technologies will be NASA/recipient co-inventions and thus may be disclosed through the NASA process with the recipient institution researcher named as co-inventor. Because these inventions might not register as recipient-reported new technologies, our precision of measurement of new technologies created under cooperative agreements is likely to be less than under grants.

We did not find any statistically significant effect of the interaction of the amount of funding per agreement and any other factors on the number of new patents issued.

Recommendation:

Given the positive effect of the amount of funding of research grants on the number of new technologies created from them, it is our recommendation that NASA Glenn, through appropriate channels within NASA, explore a policy of making larger grants in the interest of maximizing the number of new technologies likely to result from a sustained and consistently supported research effort.

The Effect of the Length of the Agreement on New Technology Creation

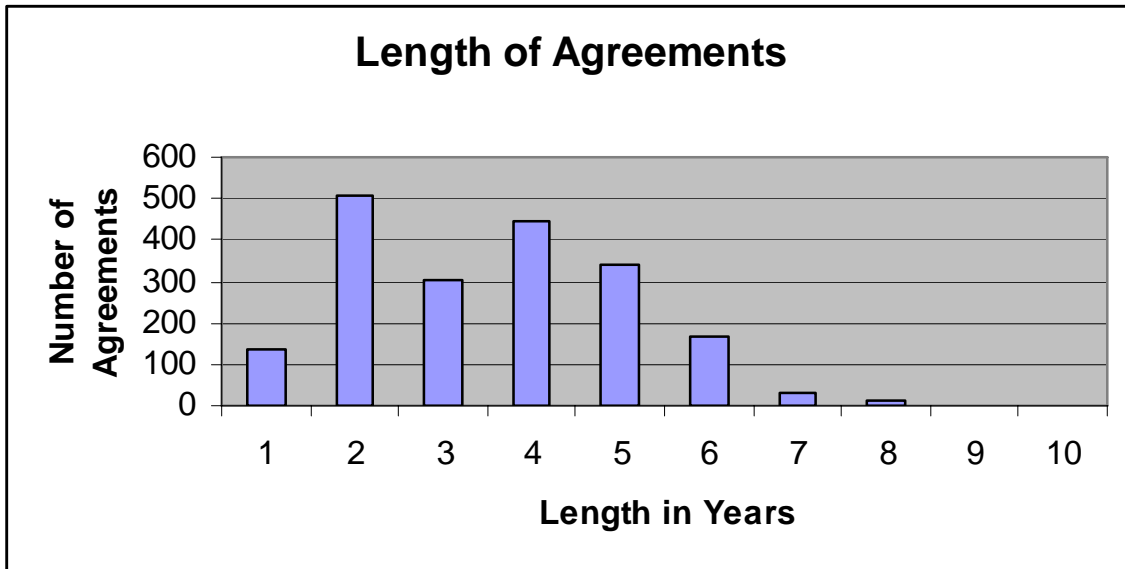
Finding #4: The longer the term of the research grant or cooperative between NASA Glenn and colleges and universities and non-profit organizations, the more new technologies the recipients create.

Researchers generally believe that longer term agreements between government agencies and funding recipients will result in the creation of more new technologies than shorter term agreements for several reasons. First, longer term agreements tend to govern more significant projects, and these projects are the ones that tend to result in the creation of more new technologies. Second, short term agreements tend to expire before the creation of new technologies occurs, resulting in a lower likelihood that the recipients will consider the government funding source as related to the creation of the new technologies. Research has shown that the average amount of time between the production of a research result by academic researchers and the commercial development of a product or a process based on that research is between 6 and 7 years on average.¹¹ Therefore, short term agreements tend not to be in force at the time that successfully commercialized academic research reaches commercial stage, reducing the incentive for researchers to attribute the creation of the new technology to the funding.

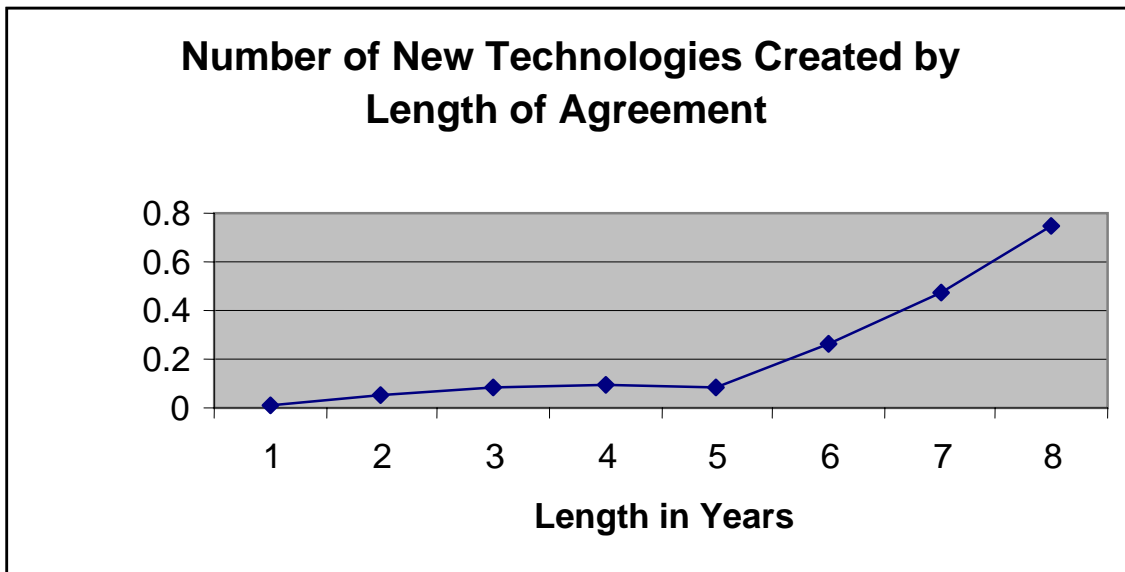
We examined the effect of the length of the agreements between NASA Glenn and the recipient organizations on the creation of new technologies. The completed agreements

¹¹ Edwin Mansfield. 1998. Academic Research and Industrial Innovation: An Update of Empirical Findings. Research Policy, 26: 773-776.

ranged from one year to ten years. The figure below shows the distribution of the number of agreements by length of the agreements (in years).



The length of the agreements had a statistically significant effect on the number of new technologies created by recipient organizations. Each year of agreement increased the rate of new technology creation by 27 percent. The figure below shows the number of new technologies created by the length of the agreement for agreements of up to eight years.



We also examined the effect of the length of the agreements on the number of new patents issued to the recipients. However, there was no statistically significant effect of the length of the agreements on the number of patented inventions created, perhaps because of the relatively small number of patented inventions.

Researchers believe that the term of agreements might not have equal effects for all recipient organizations. The length of the agreement is expected to have a greater effect on the production of new patents by non-profit organizations than colleges and universities because of the cost of establishing an organizational infrastructure for patenting. Because universities tend to have this infrastructure in place as a result of the post Bayh-Dole institutional environment, the types of agreements that they sign have relatively small effects on their tendency to patent the inventions that result from those agreements. Non-profit organizations, on the other hand, tend not to have this patenting infrastructure in place. If they have enough longer term agreements to believe that they will generate significant amounts of new technology, they will be more likely to create this infrastructure and generate more patents from their NASA Glenn agreements.

We did not find a statistically significant effect for the interaction of agreement length and type of recipient when we predicted the number of new technologies created. However, we found that the length of the agreement had a statistically significant effect on the number of patented inventions for non-profit organizations. For non-profit organizations, each year of the agreement *increased* the number of patented inventions created by 90 percent.

Finally, we examined whether other factors increased or decreased the effect of the length of the agreement on the creation of new technology and number of new patents issued. We found no statistically significant effect of the interaction of the length of the agreement and the type of project; the type of agreement; the recipient entity on the number of new technologies created or the number of new patents issued.

Recommendation:

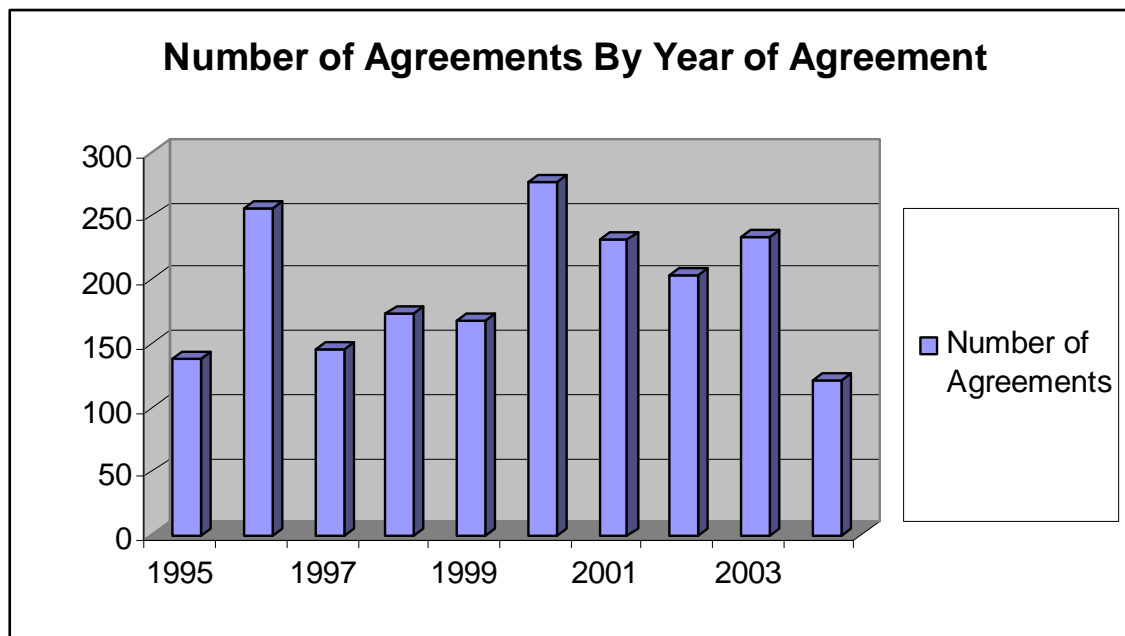
The length of agreements is affected by NASA policy regarding grants and cooperative agreements. Recently, NASA has tended to limit grants and cooperative agreements to no more than three years in duration (with some limited exceptions). It is our recommendation that NASA Glenn, through appropriate channels within NASA, explore a policy of longer-term agreements (e.g., five years, with renewal options) in the interest of maximizing the number of new technologies likely to result from a sustained and consistently supported research effort.

The Effect of the Year of Agreement on New Technology Creation

Finding #5: The more recent the agreement, the lower the number of new technologies created and new patents issue.

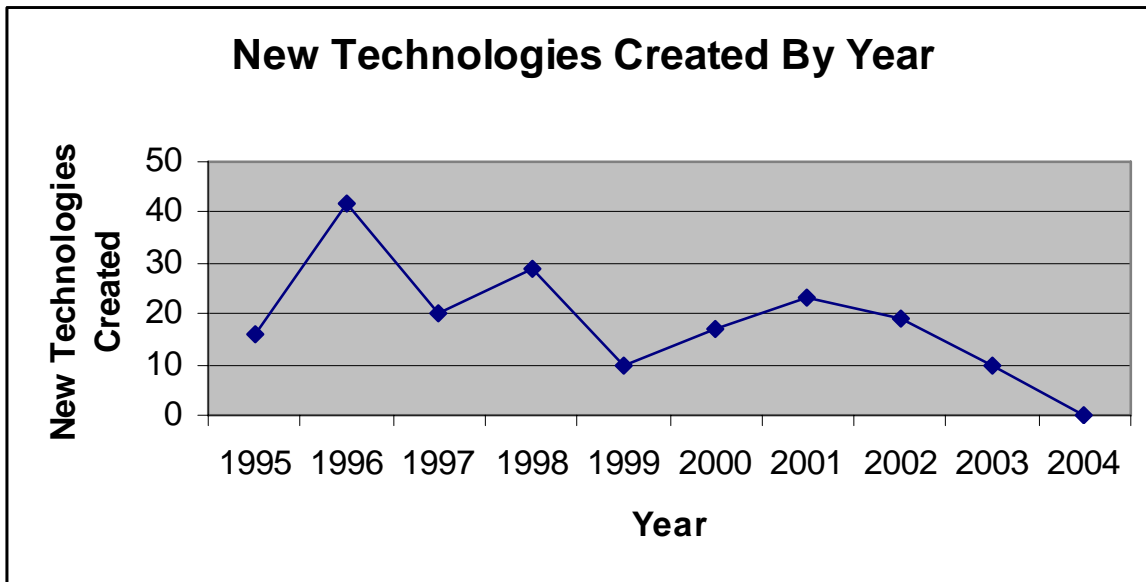
To identify the rate of production of new technologies by year of agreement, we must first determine the rate at which NASA Glenn established research grants and cooperative agreements with colleges and universities and non-profit organizations. The number of new technologies created and patents issued may be low for a particular year, not because the yield per agreement for that year is low, but because fewer agreements were established in that year.

The figure below shows the number of agreements by the year of agreement. While the count for 2004 needs to be interpreted with caution because it only reflects a partial year, a clear pattern emerges: The number of agreements signed per year was higher in the early 2000s than in the late 1990s. Therefore, one should expect *more* new technologies created and patents issued for the cohorts of agreements established in the 2000s than in the late 1990s.

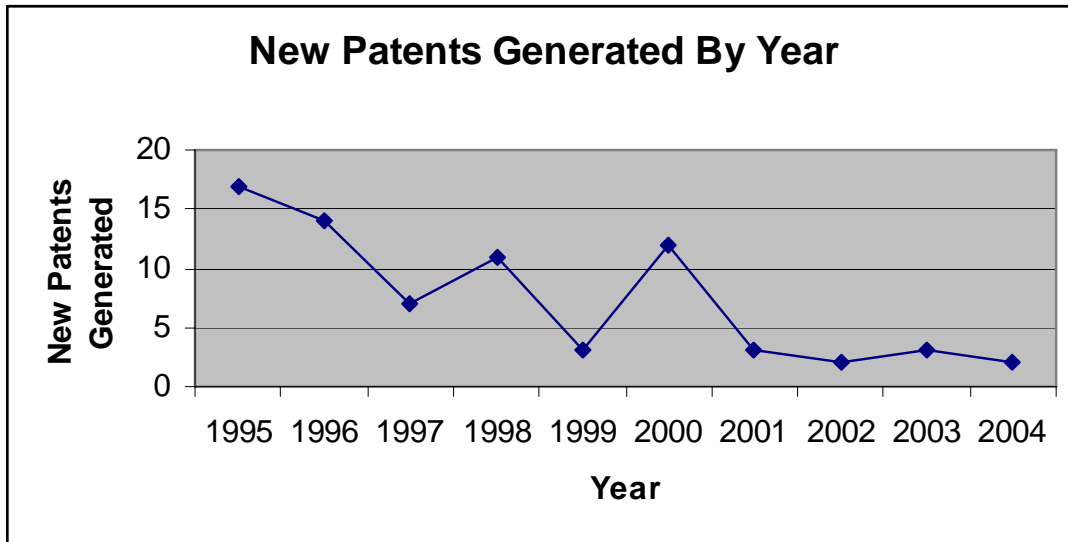


However, researchers generally believe that new technologies takes a long time to create, resulting in a lower rate of new technology creation for more recent project agreements than for agreements that occurred a longer time ago. Therefore, we should not expect the same rate of new technology creation and patent issuance to date from agreements established in the 2000s as those established in the 1990s.

We examined the effect of the year of the agreement on the number of new technologies created. The analysis shows a decreasing trend towards new technologies created as the agreements become more current. Each additional year *reduces* the number of new technologies created by 11 percent. This result, however, needs to be interpreted with caution. While it is possible that the more recent agreements are yielding fewer new technologies than previous agreements, it is also possible that it simply takes time for agreements to bear fruit. Therefore, more recent agreements have not yet resulted in new technologies.



Similar patterns are observed when we seek to explain the number of patented inventions generated. Our analysis shows that each additional year *reduces* the number of new patented inventions by 16 percent percent. The figure below shows the number of new patented inventions by year of agreement.



We believe the impact of year of agreement is closely related to the effect of duration of agreement. However, we also believe that another factor related to the reporting process may be at work. While in theory recipients are supposed to report new technologies as they are developed, regardless of the stage of the supporting agreement, in practice new technologies may not be reported until the grant/agreement closeout process is conducted at the end of the effort and all reporting requirements are rigorously enforced.

Recommendation:

Instituting an annual new technology reporting requirement, upon which the award of continued funding is contingent, would create a clear incentive for recipients to report new technologies minimally on an annual basis. While a negative impact on administrative requirements for grant recipients could potentially result from more frequent reporting, it is important to note that it is already incumbent upon recipients to report new technologies as soon as they are developed. Placing a funding incentive at intervals throughout the life of the grant or agreement, however, would enforce more frequent assessment and reporting of new technologies at an earlier stage – possibly allowing for earlier attention to new technology creation opportunities.

Geographical Distance

Finding #6: The further the recipient of the research grant or cooperative agreements is located from NASA Glenn, the lower the rate of new technology creation.

Researchers generally believe that geographic proximity is important to technology commercialization. Most new technology commercialization involves a component of tacit knowledge that cannot be written down in articles, contracts, blueprints or other

documents and requires interpersonal contact to be successful. Here our expectation is that knowledge generated at NASA Glenn is important to new technology creation by recipients of non-procurement NASA Glenn funding. As the geographical distance from NASA Glenn increases, the level of interaction between the recipients and NASA Glenn personnel on the projects declines, leading to reduced transfer of tacit knowledge.

We examined the effect of geographical distance of non-profit and academic institutional recipients of non-procurement agreements with NASA Glenn on their rate of new technology creation. We found a negative effect of distance. Each additional 100 miles away from NASA Glenn that a recipient of a grant or contract is located reduced the number of new technologies created by 4 percent and reduced the number of patented inventions by 8 percent.

We examined whether the patterns described above for new technology creation also explained new patent issuance. We found no statistically significant effect of geographical distance on the number of patented inventions created by non-procurement funding recipients, perhaps because of the small number of patented inventions.

Recommendation:

NASA Glenn and its intermediary not-for-profit organizations with specific connections to institutions in close proximity to NASA Glenn - such as OAI with its relationships to Ohio universities and industry - should exploit this effect to the maximum extent possible by engaging in focused collaborative efforts to maximize the yield of new technologies.

Categories of Projects

Finding #7: New patent generation is higher for advanced development projects than for other types of projects.

Researchers believe that the rate of new technology commercialization increases as projects become more applied. That is, the rate of technology commercialization is lower for basic research than for applied research, which is lower than for development. One reason for this pattern is that basic research is, by definition, farther from commercial application. Therefore, the amount of time, effort and money spent on a basic research project needed to get to a commercial stage is higher than that for an applied development project.

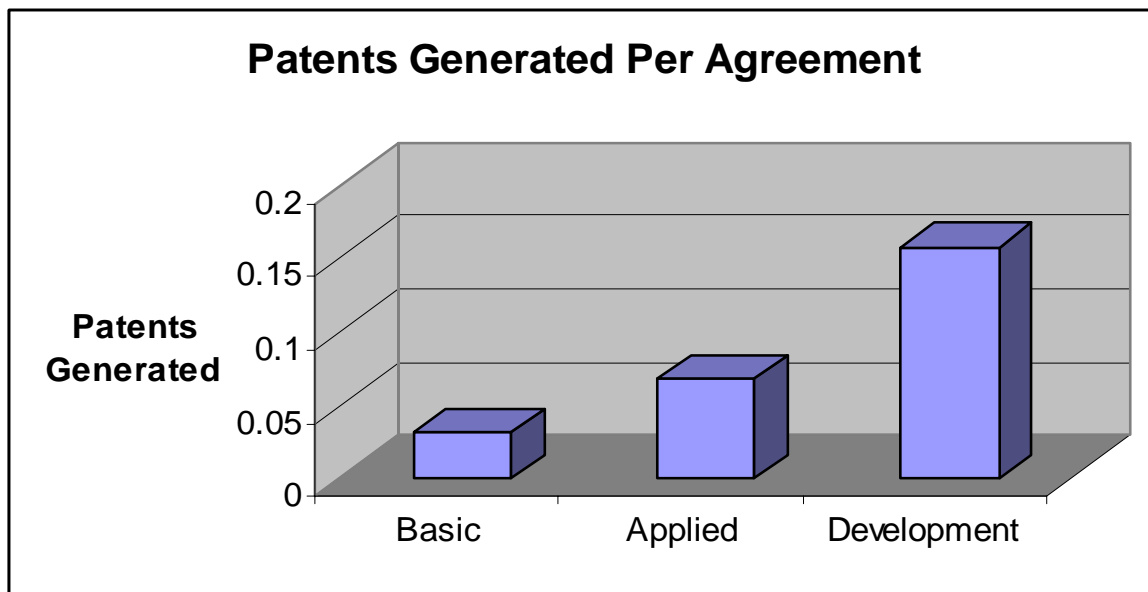
Another reason for this expected pattern is that uncertainty about the potential outcomes from projects decreases as one moves further away from more basic research. Lower uncertainty means that the new technology creation yield from the investment in projects should increase as those projects become more applied because one can more readily predict what potential applications the results of the project will have.

We examined the effect of the type of projects on the creation of new technologies and issued patents. The research grants and cooperative agreements with colleges and universities and non-profit organizations that we examined fell into three categories: basic research, applied research and exploratory development, and advanced development. The table below shows the distribution of these projects by categories of Federal Procurement Code for type of project.

Type of Project	Percentage of Projects
Basic research	85.9
Applied research and exploratory development	12.9
Advanced development	1.2

We explored whether the type of project had an effect on the creation of new technologies. The types of projects had no statistically significant effect on the number of new technologies created.

We also explored whether the type of project had an effect on the issuance of new patents. When compared to the base case of basic research projects, applied development projects had a significantly *higher rate* of new patent issuance. All other things being equal, applied development project had a rate of new patent issuance 366 percent that of basic research projects. The figure below shows the new patents generated per agreement for the different types of projects.



Recommendation:

It is unclear whether specific consideration is currently being given to the deliberate selection of efforts from the basic research stage to progress to the development stage, utilizing the same investigator and institution. This may not be viable in all cases and may not appeal to specific investigators devoted to basic research in principle. However, we believe that a process of consideration in which basic research grants that might appropriately progress to more advanced development efforts consistently applied within the broader context of NASA Glenn's mission objectives and supported by grant and cooperative agreement policy, would enhance the potential to create new technology that is potentially commercializable and that benefits NASA Glenn's mission.

Employer Status of Recipients

Finding #8: Non-profit organizations have a higher rate of new technology creation than educational institutions.

Researchers generally believe that non-profit organizations will have greater success at commercializing research than colleges and universities. One reason for this pattern is that colleges and universities do not have the creation of new technologies as a major goal. Academics seek to obtain the recognition of their scientific colleagues, which is based on the impact of their peer reviewed scholarly publications. Because new technology commercialization does not generate many academic rewards, colleges and universities are less motivated to engage in this activity than are researchers at non-profit organizations.

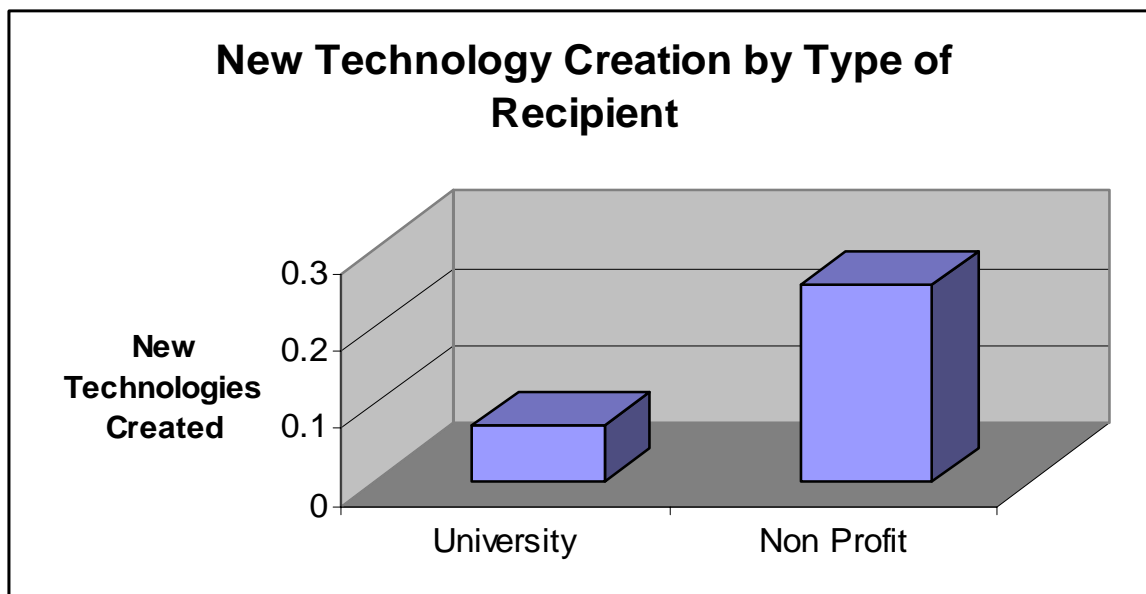
Another reason for the greater success of non-profit organizations at new technology creation is that these organizations are often set up as boundary spanning entities to bridge the gap between academia and the private sector. This role leads them to have significant private sector involvement in defining projects, shaping solutions, and otherwise enhancing the likelihood of new technology creation relative to what occurs in colleges and universities.

A third reason for the greater success of non-profit organizations is that they are able to hire different types of personnel from those at colleges and universities. Because their missions differ from that of universities, non-profit organizations can hire researchers whose goals are to develop commercializable technologies after the cutting edge academic results have been achieved. These people cannot be hired easily into colleges and universities because the cultural values and reward systems of academia do not encourage technology commercialization as much as they support scholarly inquiry. The explicit goal of finding people who can move innovation into the marketplace allows non profit organizations to develop capabilities better suited to commercialization than colleges and universities.

The table below shows the distribution of research grants and cooperative agreements by employer status of recipients.

Type of Recipient	Percentage of Agreements
Non-Profit Organizations	13.2
Colleges and Universities	86.8

We examined the effect of the employer status of the recipients on the creation of new technologies. The type of recipient had a statistically significant effect on the number of new technologies created. As the figure below shows, non profit organizations produced triple the number of new technologies as colleges and universities produced. All other things being equal, non-profit organizations had 182 percent the level of new technology production of colleges and universities. The figure below shows the raw differences between new technologies created from non-profit organizations and colleges and universities without controlling for other factors.



We examined whether the non-profit organization effect explained above was an artifact of the effect of the Ohio Aerospace Institute, the largest non-profit recipient of NASA-Glenn funding. We did not find that agreements with the Ohio Aerospace Institute generated a statistically higher or lower level of new technology creation or new patent issuance than agreements with other non-profit recipients. Therefore, the effect of being a non-profit organization described above appears to be a result of being a non-profit organization in general, not just an effect of the Ohio Aerospace Institute. The figure below shows the average number of new technologies created by the employer status of the recipients.

Recommendation:

This finding reinforces an earlier recommendation that NASA Glenn and its intermediary organizations, such as OAI, aggressively pursue collaborative partnerships between non-

profits and universities to maximize the likelihood of creating new commercializable technologies. Combined with the positive effect of geographical proximity, we believe that regional non-profit/university collaboration can result in the creation of additional new technologies by allowing universities to take advantage of the technology creation benefits afforded by non-profit organizations.

Recommendation:

This finding, again in combination with our observation on the positive effects of geographic proximity to new technology creation, also suggests that there may be significant benefit to be gained by developing focused programs whereby non profit organizations, such as OAI, with connections to the regional university community in proximity to NASA Glenn engage in formal collaboration for the specific purpose of assisting area universities with commercializing their NASA-Glenn sponsored new technology developments. Commercialization resources within NASA Glenn are increasingly limited, as are discretionary resources at non-profits and universities. Further, if the focus is on regional economic benefit, the resources for these types of efforts might best be sought at the regional level.

Type of Agreement

Finding #9: Cooperative agreements generate more new technologies than research grants.

Researchers believe that the nature of agreements signed between government agencies and colleges and universities and non-profit organizations should affect the rate of new technology creation and patent generation. Therefore, we examined whether the type of agreements influenced the rate of new technology creation and patent generation.

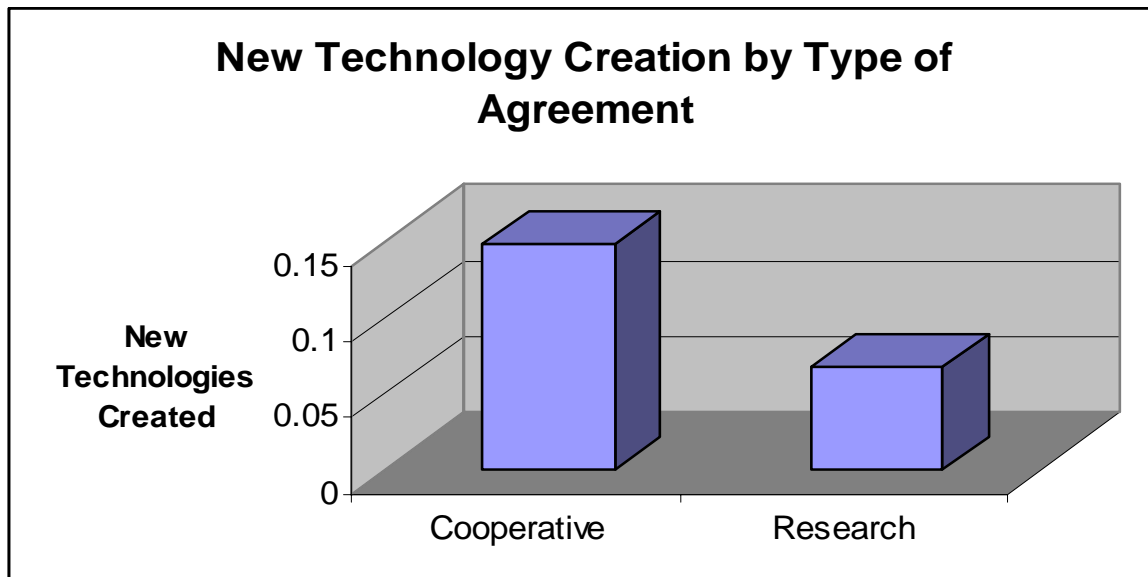
NASA Glenn establishes two types of research agreements with academic and non-profit organizations: research grants and cooperative agreements. The table below shows the distribution of agreements by type of agreement.

Type of Agreement	Percentage of Agreements
Cooperative Agreement	37.0
Research Grant	63.0

Cooperative agreements are thought to increase the rate of new technology creation over other types of agreements for two reasons. First, cooperative agreements involve the joint efforts of government agencies and the recipient entity, increasing knowledge transfer from NASA. Because NASA personnel might have important tacit knowledge that is important for technology commercialization, cooperative agreements, which make explicit use of that knowledge, should facilitate technology commercialization.

Second, cooperative agreements are more likely to generate new institutions or to expand existing ones than research agreements. Because the creation of new institutions tends to generate additional resources over and above those provided by the cooperative agreement itself, entities working on projects under cooperative agreements often have more available resources than those working under research agreements, facilitating the allocation of additional resources to technology commercialization.

Consistent with this argument, we found that number of new technologies reported varied by type of agreement. Cooperative agreements produced more than twice the number of new technologies as research agreements. All other things being equal, cooperative agreements had 116 percent the new technology production of research grants. However, there was no statistically significant difference in the number of patented inventions by the type of agreement, perhaps because of the small number of patented inventions. The figure below shows the raw differences between new technologies created from cooperative agreements and research grants without controlling for other factors.



While the above result might represent the knowledge transfer argument presented above, the difference in the number of new technologies created from cooperative agreements and research agreements may also result from the fact that, under cooperative agreements, the research is generally carried out at NASA Glenn, where there may be a more rigorous attention to new technology disclosure than when the research is carried out off site at the recipient institution.

Recommendation:

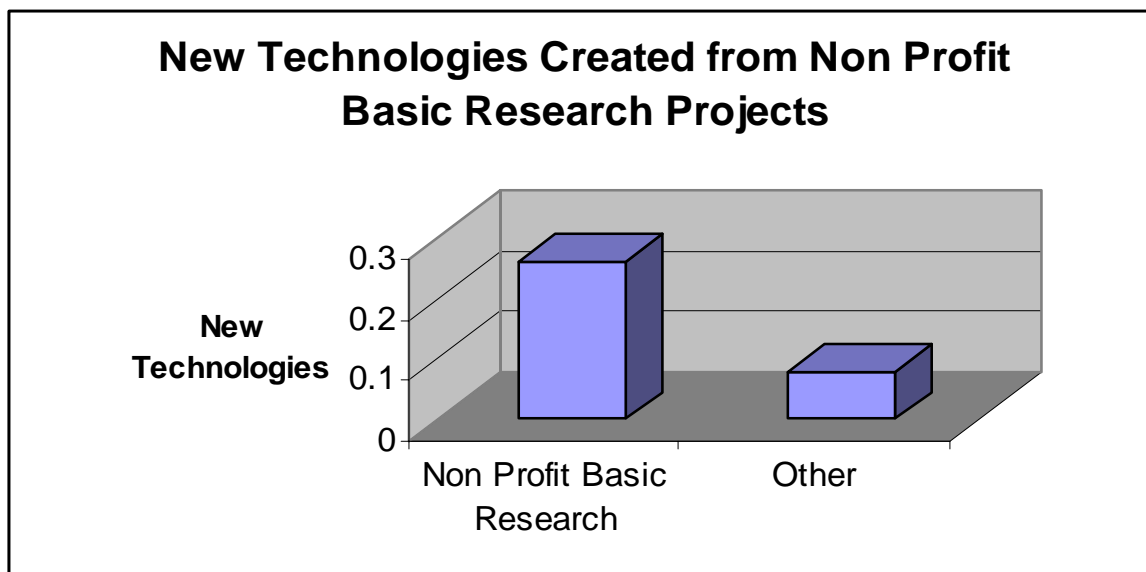
This finding suggests that there may be significant benefit to be gained by emphasizing cooperative agreements as a funding vehicle. While such consideration might not be possible in all cases, such an emphasis would enhance technology creation outcomes even given constraints on commercialization resources within NASA Glenn.

Interaction of Types of Projects and Types of Organizations

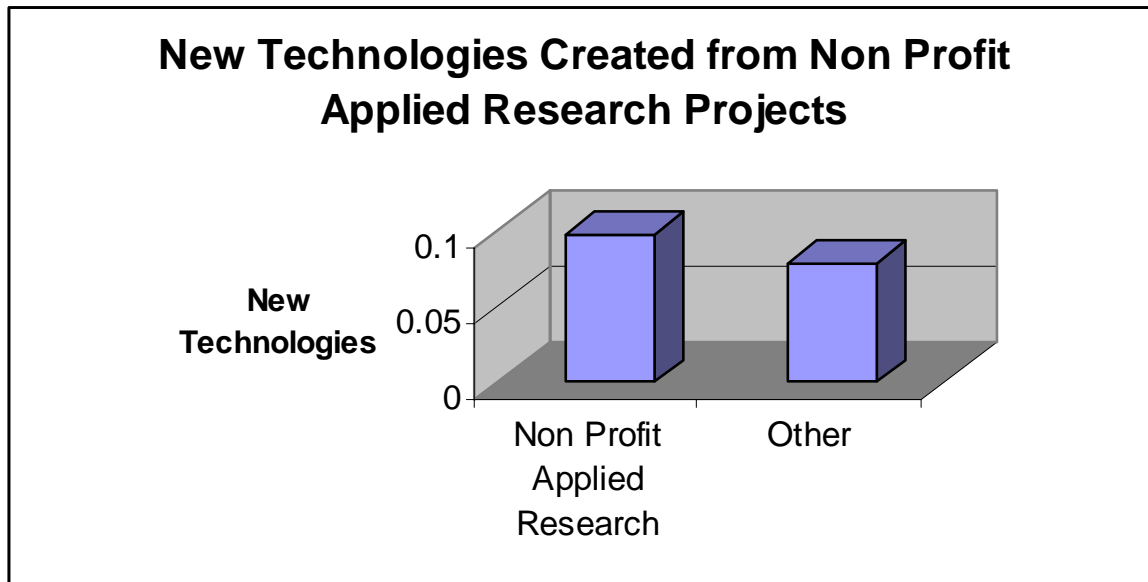
Finding #10 Non-profit organizations generate more new technologies from basic research projects than colleges and universities and fewer new technologies from applied research projects than colleges and universities.

Researchers believe that non-profit organizations and colleges and universities should be differentially suited to create new technologies from different types of projects. In particular, non-profit organizations, which are seen as buffer institutions between academia and the private sector, should generate more new technologies from applied research projects, and colleges and universities, which are at the cutting edge of science, should generate more new technologies from basic research projects.

Therefore, we examined whether non-profit institutions had different rates of new technology creation from colleges and universities for different types of projects. We found that there was a significant interaction between the employer status of the recipient and the type of project on the creation of new technology. However, the result was counter to what we had expected. Non-profit organizations generated *more* new technologies from basic research projects than from other projects. Specifically, having non-profit organizations conduct basic research increased new technologies by 320 percent. The figure below shows the raw differences between new technologies created from non profit organizations' basic research projects and other projects without controlling for other factors.



Non-profit organizations generated *fewer* new technologies from applied research and development projects than other projects. Specifically, having non-profit organizations conduct applied research and development projects reduced new technologies by 70 percent. The figure below shows the raw differences between new technologies created from non profit organizations' applied research and exploratory development projects and other projects without controlling for other factors.



One explanation for these patterns is that basic research is often more general than applied research and exploratory development. Therefore, the institutional arrangements that facilitate successful outcomes from basic research are ones that involve more multi-disciplinary teams. These teams are easier to establish in non-profit organizations than in universities, which tend to be organized on disciplinary lines. Another possible explanation is that new technology creation often results from researchers seeking to develop equipment to conduct their research. Because non-profit organizations often have more staff that can be assigned to the process of producing equipment to support research, they end up generating more new technologies than colleges and universities from their research grants and cooperative agreements.

When we examined whether these same patterns for non-profit organizations existed in predicting the number of new patents issued, we found no statistically significant effects. The patterns described above appear to exist only for new technology creation, not for the generation of new patents. One possible explanation for this differential result is that non-profit organizations are better than colleges and universities at generating more new technologies from basic research projects and worse than colleges and universities at generating new technologies from applied research projects, but that the additional new technologies created by colleges and universities from applied research projects and by non-profits from basic research projects are of relatively low quality. Therefore, these additional technologies are not patented, and these types of organizations do not have statistically different types of new patent issuance for different types of projects.

Lastly, we examined whether other factors increased or decreased the effect of the type of project on the creation of new technologies and the generation of new patents. We found no statistically significant effect of the interaction of the type of agreement and the type of project; the interaction of the amount of the agreement and the type of agreement; or the length of the agreement and the type of project on the number of patented inventions generated or new technologies created.

Recommendation:

This finding reinforces the idea that non-profit organizations and colleges and universities help to develop new technologies from different types of NASA Glenn-supported projects. Because universities and colleges are complementary to non-profits (rather than substitutes for them), this finding indicates the importance of collaboration between non-profits and universities to maximize new-technology generation strengths of both types of organizations.

Effects of Geographical Distance for Different Types of Technology

Finding #11: The greater the geographical distance of the recipient from NASA Glenn, the more new technologies are created from applied research projects.

Researchers expect that the effects of geographical distance to be different for different types of projects, different recipients of funds and different length and magnitude agreements. In particular, proximity to NASA Glenn should enhance applied research projects more than basic research projects because basic research projects are likely to involve more pure science and less information transfer from NASA personnel.

We examined whether geographical distance of the recipient from NASA Glenn had any effect on the rate of new technology creation in interaction with other factors. Although we found no effect for the interaction between geographical distance of the recipient from NASA Glenn and the amount of funding, the employer status of the recipient, the type of agreement, or the length of the agreement on the amount of new technology created, we found that the greater the geographical distance of the recipient from NASA Glenn, the **more** technologies were created from applied research projects. Each additional 100 miles away from NASA Glenn that a recipient of a grant or contract is located increased the number of new technologies created from applied research and exploratory development research grants and cooperative agreements by 6 percent.

We also examined whether the patterns described above for new technology creation explained new patent issuance. However, we found no statistically significant effect of the interaction between geographical distance of the recipient from NASA Glenn and the amount of funding, the employer status of the recipient, the type of agreement, the type of the project or the length of the agreement on the number of new patented inventions.

Recommendation:

It is unclear whether specific consideration is currently being given to the deliberate selection of types of projects and the location of the recipient. Although this consideration may not be viable in all cases, we believe that a process of consideration in which basic research projects be conducted by institutions in greater proximity to NASA Glenn and more applied development projects be conducted by institutions further away from NASA Glenn would enhance the potential to create new technology that is potentially commercializable and that benefits NASA Glenn's mission.

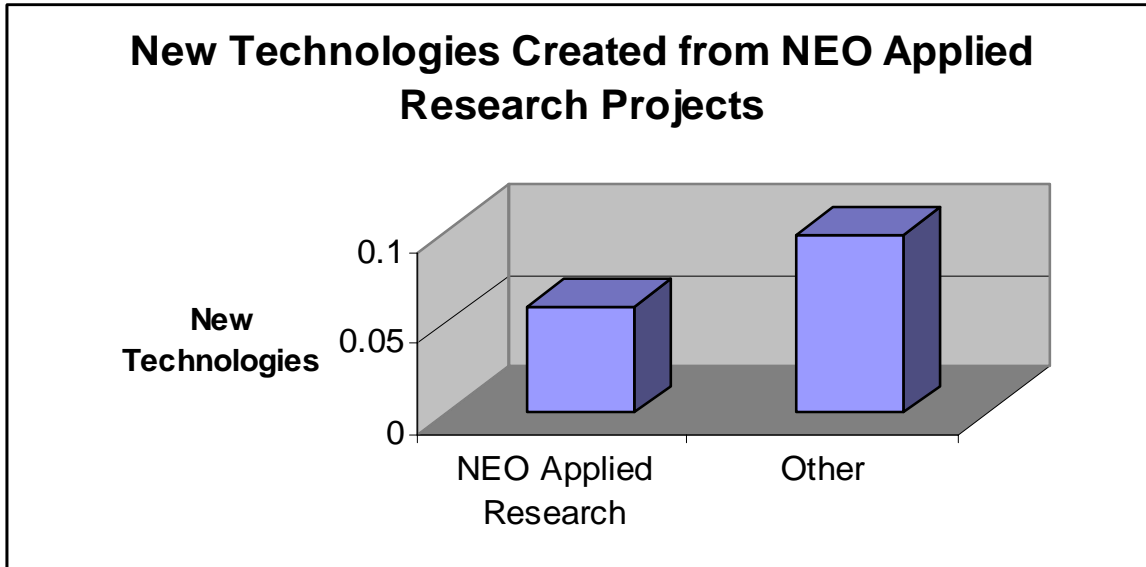
The Effect of Northeast Ohio

Finding #12: Location of the recipient in Northeast Ohio has a negative effect on the amount of new technology created and a new patent issued from applied research and exploratory development projects, and has a positive effect on the number of new patents issued from basic research projects.

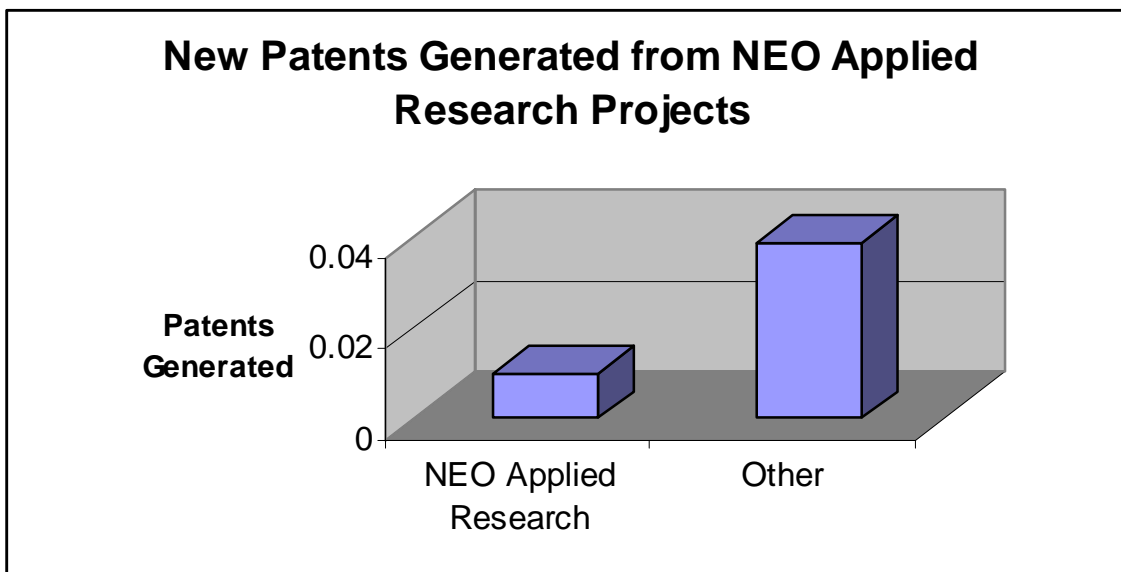
One important policy issue is whether recipients located in Northeast Ohio generate more new technology than recipients not in this geographical area. If recipients in Northeast Ohio generate more new technology and patents from NASA Glenn agreements than recipients outside Northeast Ohio then NASA Glenn administrators might be justified in providing greater funding of institutions in Northeast Ohio as a way to increase technology commercialization from NASA-funded projects.

During the period 1995-2004, recipients in Northeast Ohio received 31.4 percent of all research grants and cooperative agreements. We examined whether recipients located in Northeast Ohio created any more new technologies or issued patents from their NASA Glenn agreements than recipients not located in Northeast Ohio. We found no statistically significant differences between the recipients located in Northeast Ohio and those recipients not located in the state.

However, we also examined whether recipient location in Northeast Ohio interacted with any other factors to increase the rate of new technology creation and patent generation. Although we found no effect for the interaction between the recipient location in Northeast Ohio and the amount of funding, the employer status of the recipient, the type of agreement or the length of the agreement on the amount of new technology created, we found that recipient location in Northeast Ohio had a ***negative*** effect on the amount of new technology created when the type of project was applied research and exploratory development. Recipients located in Northeast Ohio that pursued applied research and exploratory development projects generated 29 percent fewer new technologies than recipients located outside of Northeast Ohio. The figure below shows the raw differences between new technologies created from Northeast Ohio applied research and exploratory development projects and other projects without controlling for other factors.

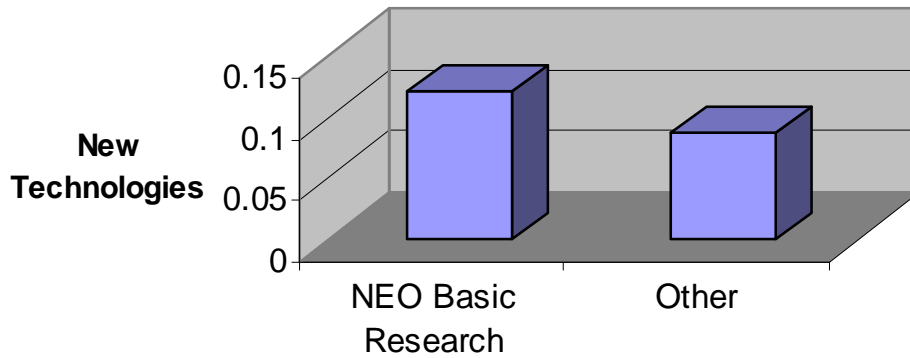


Similarly, recipients located in Northeast Ohio that pursued applied research and exploratory development generated 85 percent fewer patents as recipients located outside of Northeast Ohio. The figure below shows the raw differences between new patents generated from Northeast Ohio applied research and exploratory development projects and other projects without controlling for other factors.



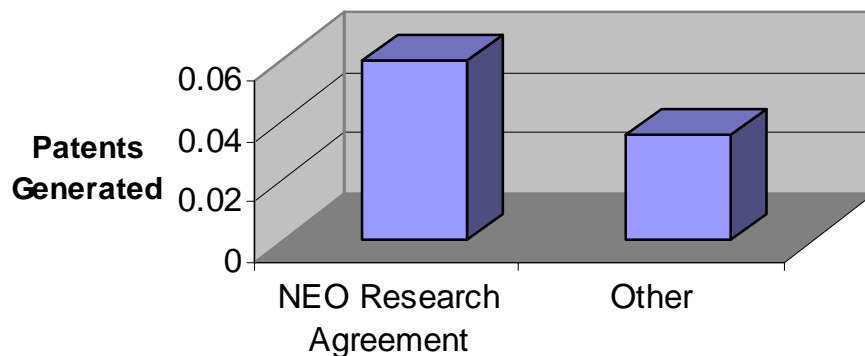
In contrast, we found that location in Northeast Ohio had a *positive* effect on the number of new patents issued when the type of project was basic research. Being in Northeast Ohio as a recipient of a basic research project increased the number of new technologies reported by 259 percent. The figure below shows the raw differences between new technologies created from Northeast Ohio basic research projects and other projects without controlling for other factors.

New Technologies Created from NEO Basic Research Projects



Moreover, we found that there was a statistically significant *positive* effect of the recipient being located in Northeast Ohio on the number of new patents issued when the agreement was a research agreement as opposed to a cooperative agreement. All other things being equal, research agreements with NASA Glenn by recipients located in Northeast Ohio generated 408 percent more patents than research agreements by recipients not located in Northeast Ohio. The figure below shows the raw differences between patents generated from Northeast Ohio research agreements and other agreements without controlling for other factors.

Patents Generated from NEO Research Agreements



Recommendation:

This finding reinforces the previous recommendation that NASA Glenn consider jointly the types of projects to be funded and the location of the recipient. We believe that a process of consideration in which basic research projects be conducted by institutions in Northeast Ohio and more applied development projects be conducted by institutions outside of the region would enhance the potential to create new technology that is potentially commercializable and that benefits NASA Glenn's mission.

Effect of Location in Ohio

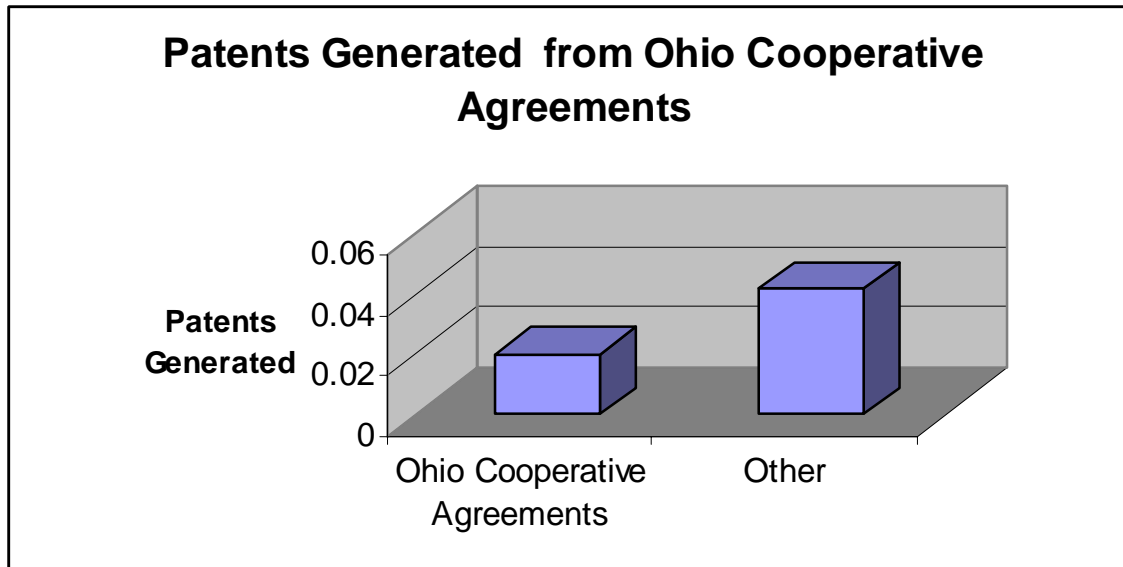
Finding #13: Recipients located in Ohio produce fewer new patents from their cooperative agreements than recipients located outside of Ohio.

One important policy issue is whether recipients located in Ohio generate more new technology than recipients not in this geographical area. If recipients in Ohio generate more new technology and patents from NASA Glenn agreements than recipients outside Ohio then NASA Glenn administrators might be justified in providing greater funding of institutions in Ohio as a way to increase technology commercialization from NASA-funded projects.

During the period 1995-2004 recipients in the state of Ohio received 35.4 percent of the research grants and cooperative agreements from NASA Glenn. We examined whether recipients located in the state of Ohio created any more new technologies or generated more patents from their NASA Glenn agreements than recipients not located in the state of Ohio. We found no statistically significant difference in the number of new technologies created or new patents issued from NASA Glenn funded research grants and cooperative agreements for recipients located within and outside the state of Ohio.

We also examined whether the effect of the interaction of the recipient being located in Ohio and other factors had any effect on the rate of new technology creation. We found no effect for the interaction between the recipient being located in Ohio and the amount of funding, the employer status of the recipient, the type of agreement, the type of project or the length of the agreement on the amount of new technology created.

However, we found that the location of the recipient in Ohio had a significant *negative* effect on the number of new patents created from the agreement if the agreement was a cooperative agreement. All other things being equal, recipients located in the state of Ohio generated 83 percent fewer new patents than cooperative agreements with recipients located outside of the state of Ohio. The figure below shows the raw differences between patents generated from Ohio cooperative agreements and other agreements without controlling for other factors.



Recommendation:

It is unclear whether specific consideration is currently being given to the deliberate selection of types of agreements and the location of the recipient. Although this consideration may not be viable in all cases, we believe that a process of consideration in which more research agreements be formed with Ohio institutions and more cooperative agreements be conducted with non-Ohio institutions would enhance the potential to create new technology that is potentially commercializable and that benefits NASA Glenn's mission.

Industrial Infrastructure

Finding #14: There are no statistically significant effects of the industrial infrastructure of the metropolitan statistical area in which the recipient was located on the rate of new technology creation or patent generation.

Researchers generally believe that there is a relationship between the industrial infrastructure surrounding public sector innovators and the creation of new technologies by those innovators. Knowledge transfer between industry and the public sector enhances the innovative ability of public sector innovators. In particular, when companies in a region operate in technical fields to which the public sector innovation is relevant, they often provide useful information to the public sector innovators.

In addition, the presence of private companies interested in the research and development projects of the public sector innovators increases the likelihood that those public sector innovators will obtain private sector financial resources useful for innovation. Both of these mechanisms are the case particularly for newer and smaller firms, which tend to

affect and be affected more by public sector innovation than is the case for larger and older firms.

Because of these patterns, we examined the effect on new technology creation and patent generation of several dimensions of the industrial infrastructure of the metropolitan statistical area where the recipients of NASA funding were located: manufacturing intensity; technological production intensity, business intensity, and scientific and engineering workforce intensity. We found that none of these indicators of the industrial infrastructure where the recipient was located had any statistically significant effect on the creation of new technologies or the numbers of new patents issued.

The lack of the effect for industrial infrastructure might be explained by several factors. First, the production of new technologies for NASA at colleges and universities and non-profit organizations might not require much knowledge transfer or other linkage to the private sector firms located near the institutions. Therefore, the industrial infrastructure in the region around the institutions has no effect on the production of new technologies. Second, the presence of an industrial infrastructure that is related to the projects conducted at the colleges and universities and non-profit organizations receiving the NASA Glenn funding might create competition for the institutions' intellectual resources. The poaching of talented graduate students and the employment of faculty as consultants might exert a countervailing effect on new technology creation that mitigates the positive effects of industrial infrastructure suggested above.

Recommendation:

This finding suggests that research grants and cooperative agreements with colleges, universities and non-profits can be conducted in wider range of locations than is commonly believed. While the industrial infrastructure in particular geographic locations may influence the activities of private sector firms to produce new technologies for NASA Glenn, the presence of specific types of industrial infrastructure or industrial clusters is not a prerequisite for new technology creation on NASA-funded projects at colleges, universities and non-profit organizations. We believe that a process of consideration in which the industrial infrastructure of the area around the proposing college, university or non-profit organization not be considered would not adversely affect the potential to create new technology that is potentially commercializable and that benefits NASA Glenn's mission.

University Quality

Finding #15: Academic institution quality increases the number of patents issued by academic institution recipients of NASA Glenn research grants and cooperative agreements for basic research projects, but decreases it for applied research and exploratory development projects.

Researchers generally believe that there is a relationship between the quality of colleges and universities and their ability to commercialize research. On average, the better the institution, the better the skills of the researchers undertaking the project, and the greater the likelihood that researchers will produce a new technology from a NASA Glenn-funded project. Moreover, better universities receive more complementary resources that enhance the development of new technologies from NASA funded non-procurement agreements because stakeholders of colleges and universities perceive these entities as more likely than other institutions to generate commercial outcomes from research.

We examined the effect of university quality on new technology creation and new patent generation for those non-procurement agreements made with colleges and universities. To measure college and university quality, we examined the average overall ranking of science and engineering departments recorded by the National Research Council's national ranking of doctoral programs. Our comparison showed no statistically significant difference in the number of new technologies created by colleges and universities as a function of their academic quality. However, our comparison showed a very strong effect of academic quality on the number of patented inventions generated from agreements between NASA Glenn and educational institutions. Each one point rise in the National Research Council's ranking of the academic institution's doctoral programs *increased* the number of patented inventions by 258 percent.

We also sought to determine if there was an interaction between the effect of university quality and other factors on the number of new technologies created and the number of new patents issued. We observed no statistically significant effect of academic institution quality in interaction with the type of project – basic research, applied research, development or provision of educational services. Furthermore, we observed no statistically significant effect of academic institution quality in interaction with the amount of research funding. However, we observed a statistically significant *negative* effect of the interaction between academic institution quality and applied research and development projects and a statistically significant *positive* effect of the interaction between academic institution quality and basic research projects on the number of new patents created. For agreements covering applied research projects, each one point rise in the National Research Council's ranking of the academic institution's doctoral programs decreased the number of patented inventions by 81 percent. In contrast, for agreements covering basic research projects, each one point rise in the National Research Council's ranking of the academic institution's doctoral programs increased the number of patented inventions by 309 percent.

These results might be explained by an important difference between more highly ranked and less highly ranked colleges and universities. Creating new technologies from NASA-funded applied research projects might be possible with average quality scientists and engineers (present at lesser ranked institutions) and might not require cutting edge researchers. In fact, these projects might take time away from the production of scholarly research and therefore be more productively undertaken in institutions of lesser rank. As a result, more highly ranked institutions might generate fewer patents from their NASA-

funded applied research projects even though they have generated more patents from their NASA-funded projects overall.

We examined the rate of new technology creation and new patent issuance by the two largest educational agreement partners of NASA Glenn: Case Western Reserve University and Cleveland State University. During the 1995 to 2004 period, Case Western Reserve University received 5.8 percent of research grants and cooperative agreements with NASA Glenn. Cleveland State University received 4.7 percent of the research grants and cooperative agreements during the same period. We find that the rate of new technology creation and new patent creation by these two institutions is statistically indistinguishable from the average rate of new technology creation and patent issuance by recipients of NASA Glenn non-procurement funding.

Recommendation:

It is unclear whether specific consideration is currently being given to university quality in conjunction with the types of projects being supported by NASA-Glenn. Although this consideration may not be viable in all cases, we believe that a process in which more basic research projects be conducted with colleges and universities more highly ranked by the National Research Council and more applied research projects be conducted with colleges and universities less highly ranked by the National Research Council would enhance the potential to create new technology that is potentially commercializable and that benefits NASA Glenn's mission.

Conclusions and Recommendations for Increasing the Rate of New Technology Creation and New Patent Production from NASA Glenn Research Grants and Cooperative Agreements with Colleges and Universities and Non-profit Organizations:

14. Treat colleges, universities and non-profit organizations as important extenders of the new technology production activity of NASA Glenn.
15. Recognize that the research and development cost of producing new technologies and patented inventions from NASA-Glenn funded research grants and cooperative agreements at colleges, universities, and non-profit organizations is going to be the same as that of producing all new technologies and patented inventions at these institutions, and that increasing the total amount of funding at these institutions is going to be necessary to generate significant increases in the amount of technology creation from NASA-Glenn funded projects at these institutions.
16. Consider advocating that NASA policy on grants and cooperative agreements that favor longer initial periods (e.g., five years) and allows for options for renewal.
17. Assess whether the goal of NASA Glenn is to increase the production of new technologies, new patents or both when designing NASA-Glenn's technology commercialization strategy; the factors that increase the number of new technologies are not the same as the factors that increase the numbers of new patents issued.

18. Implement annual new technology reporting requirements for recipient institutions, perhaps connected with the award of continued funding, to ensure the new technologies are reported on at least an interim basis throughout the progress of the grant or cooperative agreement.
19. Develop policies to encourage institutions in close proximity to NASA Glenn to engage in focused collaborative efforts with other institutions to take advantage of geographic proximity effects on technology commercialization.
20. Increase collaboration between non-profit institutions and area colleges and universities to maximize the strengths of each type of institution in the creation of new technologies under grants and cooperative agreements and basic research through advanced development projects.
21. Consider developing and implementing a pilot project supported by regional resources in which a non-profit NASA intermediary collaborates with universities specifically on the commercialization of NASA Glenn-sponsored research and technology in which non-profit organization recipients of NASA Glenn research grants and cooperative agreements conduct basic research projects and college and university recipients of NASA Glenn research grants and cooperative agreements conduct applied research and exploratory development projects.
22. Consider implementing focused consideration of basic research projects for progression to more advanced stages of development with the same investigator and institution.
23. Emphasize cooperative agreements as a funding vehicle to enhance technology creation outcomes.
24. Consider matching types of projects and types of agreements to the location of the recipient to maximize the advantages at generating technology from NASA Glenn funded projects of institutions in different locations.
25. Evaluate projects from organizations without concern for the industrial infrastructure in the area surrounding the recipient institution.
26. Consider developing a policy of matching the type of project to college and university research quality to maximize the advantages of different institutions in generating technology from NASA Glenn funded projects.