RIPPLE EFFECT
COMMUNICATIONS, INC

Final Report

2015-2016 COMPREHENSIVE EVALUATION OF THE NATIONAL CANCER INSTITUTE (NCI) INNOVATIVE MOLECULAR ANALYSIS TECHNOLOGIES (IMAT) PROGRAM

August 31, 2016

August 31, 2016

RIPPLE EFFECT COMMUNICATIONS, INC. | 2400 RESEARCH BOULEVARD, SUITE 305, ROCKVILLE MD 20850

Prepared for the National Institutes of Health

Tony Dickherber, PhD

Program Director, Innovative Molecular Analysis Technologies

National Cancer Institute

National Institutes of Health

Prepared under Contract Number HHSN263200800077B

By Jennifer Reineke Pohlhaus, PhD, Amy Bielski, MBA, Kristy Riordan, PhD, and Julia Rollison, PhD from Ripple Effect Communications, Inc.

Supported by Courtney Carta, MPH, Stacy Howes, PhD, Alexis Bender, PhD, Joseph Whelan, MS, and Esther Lau, MPH, from Ripple Effect Communications, Inc.; and Kirk Baker, PhD, from Lexical Intelligence.

Survey and interview protocols and instruments were reviewed by the Office of Human Subjects Research (Protocol #12656) and determined to be excluded from institutional review board (IRB) review. Data collection was approved by the Office of Management and Budget (OMB) under OMB control number 0925-0720.

Contents

List of Tables ..... e
List of Figures ..... f
Executive Summary i
Overview i
Evaluation Design and Methodology i
Summary of Findings i
Detailed Findings of Evaluation Questions v
Conclusions viii
Recommendations for the IMAT Program viii
Recommendations for Future Evaluations ix
Outline of Report ix
Introduction 1
Selected Trans-NIH Programs Support Innovation 1
Technology Development and the National Cancer Institute 1
Purpose of the Current Evaluation 2
Evaluation Design and Methodology 3
Conceptual Framework 4
IMAT Group Selection Process 6
Comparison Group Selection Process 7
Comparison Group Limitations 9
End User Selection Process 10
Data Collection Sources 12
Archival Data 13
Web-based Survey 14
IMAT PD/PI Interviews 15
IMAT End User Interviews 16
Findings 18
Initial Investment 18
Feedback on Grant Application Process 18
Principal Investigators and the Research Team 21
Previous Research 21
Advantages of the Technologies 23

Anticipated Outcomes 23
Prior Funding 23
High Risk/High Reward Concepts 24
NIH Support and Interactions with NIH Program Officers and Grant Staff 25
Knowledge Contributions, Collaborations, and Funding 27
Comparison Group Interactions with Program Staff 29
Program Activities 30
Advancing the Technology 30
Institutional Support 30
Program Outputs 31
IMAT Publication Trends 31
IMAT Patent Considerations and Limitations 43
Other Output Measures 52
Short-Term and Long-Term Outcomes 56
Funding to Advance Technology 56
Technology Application 59
Technology Dissemination 60
Improving Research Standards and Ability to Diagnose and Treat Cancer 67
Types of Technology Produced 68
End User Use of Technology 74
Additional Program Feedback 76
Comparison Group 76
IMAT Program Feedback 77
Support 77
Criticism 78
Moving Forward 78
Conclusions 79
Summary of the Findings 79
Initial Investment 79
Program Activities 79
Short-, Medium-, and Long-Term Outcomes 80
Recommendations 81
Value of the IMAT Evaluation 81
Recommendations for the IMAT Program 82

Recommendations for Future Evaluations 82
Appendix A – References A1
Appendix B – The IMAT Program B1
Purpose B3
Mechanisms of Support B3
IMAT Thematic Areas B4
Program Stakeholders B5
IMAT Applications and Awards B5
Funding Mechanism B6
Grant Funds B7
Grant Awards by Thematic Area B7
New and Previous IMAT Principal Investigators B8
History of IMAT Evaluation Activities B9
Appendix C – Case Study Evaluations of IMAT Grantees C1
PI: NOLLING, JORK N. C2
PI: WANG, ZHENGHE C3
PI: DAVALOS, RAFAEL VIDAL; CRAMER, SCOTT D. C4
PI: CARON, MARC G. C5
PI: AKSAN, ALPTEKIN C6
PI: LAM, KIT S. C7
PI: DAYTON, PAUL A; JANZEN, WILLIAM PERRY C8
PI: STEINMAN, RICHARD A. C9
PI: TAO, NONGJIAN C10
PI: CARTEGNI, LUCA C11
PI: GRZYBOWSKI, BARTOSZ ANDRZEJ C12
PI: LIOTTA, LANCE ALLEN C13
PI: ZU, YOULI C14
PI: WANG, TZA-HUEI C15
PI: HSIAO, SHIH-CHIA; FRANCIS, MATTHEW B. C16
PI: JEFFREY, STEFANIE S. C17
PI: LIOTTA, LANCE ALLEN C18
PI: TAVANA, HOSSEIN; LUKER, GARY D. C19
Appendix D – History of Evaluation Activities D1
2007 Feasibility Study for Outcome Evaluation of IMAT Program, Macro International D1

2008 Outcome Evaluation Report, SAIC Corporation D2
2010 Evaluation Update Report, Science & Technology Policy Institute D2
2013 Targeted Evaluation Activities, Thomson Reuters – Custom Analytics Group D3
Appendix E – FOAs Included in IMAT and Comparison Groups E1
Appendix F – Complete List of FOAs Available for Comparison Group F1
Appendix G – Archival Data Collection Methodology G1
Obtaining Grant Information G1
Obtaining Patent Information G8
Publication Methodology G10
Appendix H – Evaluation Data Collection Instruments H1
2015 IMAT Evaluation Web-based Survey H1
Successful IMAT Awardees Interview Protocol H11
Appendix I – Institutions and Organizations with IMAT Awards I1
Appendix J – Principal Investigators with IMAT Awards J1
Appendix K – Preceding Technologies K1
Appendix L – Funded Technologies and Methodologies L1
Appendix M – Abbreviations M1

List of Tables

Table 1. Evaluation Questions and Answers iii
Table 2. Evaluation Questions and Relevant Data Source 5
Table 3 Considerations for Comparison Group Selection 10
Table 4. Number of Awards for End User Interview Consideration by Fiscal Year 11
Table 5. Archival Data Assumptions 14
Table 6. Web-based Survey Response Rates by Study Group 15
Table 7. End User Interviewees by Technology Type 17
Table 8. Survey Data on Research Team Composition 21
Table 9. Reported Disciplines of Collaborators 28
Table 10. Total Non-Distinct Publications by Funding Mechanism 33
Table 11. Journals with the Highest Percentage of Publications 38
Table 12. IMAT-Funded Institutions with the Highest Number of Publications 39
Table 13. Top Institutions with the Highest Number of Publications by Institution and Funding Mechanism 39
Table 14. IMAT PD/PIs with the Highest Number of Publications 40
Table 15. Comparison Group PD/PIs with the Highest Number of Publications 40
Table 16. IMAT PD/PIs with the Highest Number of Publications by Funding Mechanism 41
Table 17. Comparison Group PD/PIs with the Highest Number of Publications by Funding Mechanism 41
Table 18. Distinct Publications Produced by IMAT (N=705) and Comparison Group (N=473) 42
Table 19 Patent Applications and Awards by Mechanism 44
Table 20. Non-Distinct IMAT Patent Applications and Awards by Funding Mechanism 46
Table 21. Top Patent Applications and Awards by Institution 48
Table 22. Top Institutions for Patent Activity by Funding Mechanism 48
Table 23. Top Principal Investigators by Number of Patent Applications 49
Table 24. Top Principal Investigators by Patent Applications and Awards by Funding Mechanism 49
Table 25. Patent Applications for IMAT and Comparison Groups 50
Table 26. Patent Awards for IMAT and Comparison Groups 50
Table 27. Number of Patent Applications and Awards by Patent Class by Patent Classification 51
Table 28. Top Categories of Intended Use 73
Table 29. FOAs from 1998 to 2013 with Release and Expiration Dates 1
Table 30. IMAT Grantees Included in Case Studies Evaluation 1
Table 31. IMAT R21 and R33 FOAs by Thematic Area 1
Table 32. IMAT SBIR/STTR FOAs by Thematic Area 2
Table 33. Comparison Group FOAs by Fiscal Year and Award Type 3
Table 34. Full List of FOAs Considered for Comparison Group 1
Table 35. PD/PIs with IMAT Awards 1
Table 36. Abbreviations Used in this Report 1

List of Figures

Figure 1 IMAT Program Support in the Context of the Technology Development Pipeline 2
Figure 2. IMAT Outcome Evaluation Conceptual Framework/Logic Model 4
Figure 3. Summary of IMAT Grants, Data Collection Sources, and Number of Collection Points 6
Figure 4. Comparison Group Selection Process 7
Figure 5. Number of Grants Awarded to IMAT and Comparison Groups 8
Figure 6. Average Dollar Amount Awarded to IMAT and Comparison Groups by Funding Mechanism 9
Figure 7. Sources for Collecting Data on Evaluation Questions 13
Figure 8. End User Recruitment Process 17
Figure 9. Coupled or Uncoupled Preferences 20
Figure 10. Other Funding PD/PIs Would Have Pursued Without IMAT Funding 22
Figure 11. Anticipated Uses for IMAT Technology 23
Figure 12. Funding Amounts Obtained Prior to IMAT Award 24
Figure 13. Matrix of Self-Reported Ratings of Risk and Reward Levels of Technology/Methodology 24
Figure 14. Suggestions to Enhance the PI Meeting 26
Figure 15. Total Publications by Grant Fiscal Year 32
Figure 16. Number of Publications Produced by Coupled and Uncoupled Grants 33
Figure 17. Percentage of Publications Produced by Funding Mechanism 34
Figure 18. Number of Publications by Theme and Funding Mechanism 34
Figure 19. Percentage of Grants that Account for Publications (N=2,244) among IMAT Awardees by Quartile 35
Figure 20. Percentage of Publications, Banded, by Thematic Code 35
Figure 21. Number of Citations by Year of Citation 36
Figure 22. Number of Citations per Fiscal Year by Number of Publications 36
Figure 23. Publications by Fiscal Year of Grant 42
Figure 24. Percentage of Grants that Account for Publications (N=736) Among Comparison Group by Percentiles 43
Figure 25. Patent Applications and Awards by Year of Grant Application 45
Figure 26. Patent Applications and Awards by Year of Grant Application 45
Figure 27. Number of Patent Applications and Awards by Thematic Area 46
Figure 28. Grants Accounting for Patent Applications and Awards (N=461) among IMAT Awardees by Quartile 47
Figure 29. Percent of Patent Activity Represented in the Top Percentages by Thematic Area 47
Figure 30. Status of Intended Developmental Pursuits among IMAT Grants 53
Figure 31. Status of Intended Developmental Pursuits within the Comparison Group 54
Figure 32. Status of Intended Developmental Pursuits among IMAT Grants by Funding Mechanism 54
Figure 33. Status of Intended Developmental Pursuits within the Comparison Group by Funding Mechanism 55
Figure 34. Overlap in Developmental Pursuits within the IMAT Group 55
Figure 35. Funding Obtained During the Grant Period (Excluding the IMAT Award) 57
Figure 36. Comparison Group Funding Obtained During the Grant Period (Other than the Main Grant). 57

Figure 37. Funding Obtained During the Grant (Other than IMAT Grant) by Funding Mechanism 58
Figure 38. Comparison Group Funding Obtained During the Grant (Other than the Main Grant) by Funding Mechanism 58
Figure 39. Reasons for Technology Not Achieving Marketability According to IMAT Grantees 61
Figure 40. Development Stage Prior to Receiving Award for IMAT Awardees and Comparison Group 63
Figure 41. Development Stage after Receiving Award for IMAT Awardees and Comparison Group..... 63
Figure 42. Stage Progression and Regression through Developmental Stages for IMAT Awardees and Comparison Group 64
Figure 43. Stage of Development at IMAT Grant Conclusion by Funding Mechanism 65
Figure 44. Stage of Development at Grant Conclusion for Comparison Group by Funding Mechanism ... 65
Figure 45. Stage of Development for IMAT Grants at Time of Study by Funding Mechanism 66
Figure 46. Stage of Development for Comparison Group at Time of Study by Funding Mechanism..... 66
Figure 47. Reported Impact of IMAT-funded Technology 67
Figure 48. Reported Impact of Comparison Group Technology 68
Figure 49. Type of Research Methodologies and Technologies 69
Figure 50. Application Areas of Research and Technology 70
Figure 51. Types of End Users, Described by PD/PIs 71
Figure 52. Types of Private Sector End Users, Described by PD/PIs 71
Figure 53. Intended Major Uses 72
Figure 54. IMAT Applications and Awards by Fiscal Year 6
Figure 55. IMAT Applications and Awards Resulting from R21/R33 Funding Opportunities 6
Figure 56. IMAT Applications and Awards Resulting from SBIR/STTR Funding Opportunities..... 7
Figure 57. Dollar Amount Awarded by Fiscal Year and Funding Mechanism 7
Figure 58. IMAT Grant Awards by Thematic Area 8
Figure 59. Average Dollar Amount Awarded by Thematic Area and Funding Mechanism 8
Figure 60. IMAT Grants Awarded to PD/PIs, by Previous Award Status 9

Executive Summary

Overview

The National Institutes of Health (NIH) supports innovation and recognizes its potential to accelerate the pace of discovery in biomedicine by encouraging and supporting pioneering biomedical research through various grant programs. Toward this end, the National Cancer Institute (NCI) launched the Innovative Molecular Analysis Technologies (IMAT) program in 1998 to support the development of highly innovative technologies to advance cancer research and clinical care capabilities, with an ultimate goal of bringing the technologies into development to benefit researchers, clinicians, and cancer-relevant communities and patients.

To investigate whether the IMAT program is achieving maximum impact in cancer research, NCI pursued a comprehensive and rigorous evaluation to assess the process and outcomes of the IMAT program and to seek opportunities for NCI to improve the program's usefulness. The focus of the evaluation was to understand the successes of supported technologies. Evaluation efforts (September 2014 –July 2016) were overseen by a trans-NIH Evaluation Advisory Committee (EAC) composed of Federal officers and evaluation specialists.

Ripple Effect Communications, Inc. (Ripple Effect) conducted the evaluation, which consisted of multiple methods of data collection (e.g., web-based surveys, bibliometric methods, and interviews with End Users and Project Director/Principal Investigators [PD/PIs]) and, where possible, compared findings to a Comparison Group.

Evaluation Design and Methodology

This evaluation was guided by the IMAT program logic model used for the 2007 Feasibility Study for Outcome Evaluation, with modifications based on Ripple Effect input and discussions with the Program Director, Dr. Tony Dickherber. The current conceptual framework for the IMAT program is presented in Figure 2 in the main body of this report.

The study design provided for several data sources: archival data, web-based surveys, phone interviews with PD/PIs, and phone interviews with technology End Users. To have a metric of comparison for conclusions about the IMAT program, the evaluation team designed a Comparison Group of PD/PIs, pulled from a matched set of Funding Opportunity Announcements (FOAs). The Comparison Group was useful to provide rigor for the conclusions drawn from the Archival Data and Web-based Survey Data Sources. The Interview (PD/PI and End User) Data Sources were used only for the IMAT program; data was not collected from the Comparison Group. The selection and sampling plan for each of the data sources is shown in Figure 3 in the main body of this report.

Summary of Findings

The evaluation concluded that IMAT has a significant impact on scientific advancement within cancer research through manuscript publications and commercialization of IMAT funded technologies and methodologies. IMAT-funded PD/PIs published more manuscripts with higher impact factors and more manuscripts per $100,000,000 compared to the Comparison Group. Similarly, IMAT-funded PD/PIs applied for more patents and received more patent awards per $100,000,000 compared to the Comparison Group.

Participants in the evaluation, PD/PIs and End Users, were extremely positive about the importance of the IMAT program in regards to advancing cancer research. PD/PIs overwhelmingly stated their support for the continuation of the program. Many noted that their research would not exist or would be severely delayed if not for IMAT funding. They described IMAT funding as "unique," "crucial," and "essential" for moving cancer research forward because it allows for the exploration of risky, but potentially innovative and important, cancer research technologies and methodologies. End Users were similarly enthusiastic about the program, and they stated that the technologies and methodologies produced by IMAT-funded grants were critical and/or extremely important. End Users indicated that such technologies and methodologies maximized resources, increased knowledge, and furthered understanding of disease progression, thereby catalyzing cancer research.

1. As reported by the PD/PIs, the IMAT program fills a gap and funds major contributions to cancer research.
    - IMAT fills a very specific niche in cancer research that encourages cutting-edge, innovative research.
    - Almost a third (28%) of PD/PI interview participants stated that they would not pursue alternative funding mechanisms if had not receive IMAT funding. Similarly, 27% noted that they would pursue other funding mechanisms, but would likely face challenges due to the innovative nature of the proposed research.
    - Advantages of the technology included filling gaps in the research (15%), cost-effectiveness (8%), scalability (4%), ease or automation (19%), greater applicability to existing research (18%), and advances specific to the IMAT technology (35%).
2. Using a Comparison Group for reference, the IMAT program was successful in funding major contributions to cancer research.
    - Under the R21/R33 funding mechanism, grants from the IMAT program resulted in significantly more publications than the Comparison Group (Mean=5.3 vs. 3.3), but under the SBIR/STTR funding mechanisms, grants from the IMAT program were similarly productive (Mean=3.3 vs. 2.2). Under any funding mechanism, grants from the IMAT program resulted in significantly higher impact factors (R21/R33 IMAT Mean=7.0 vs. Comparison Group Mean=5.3; SBIR/STTR Mean=4.9 vs. Comparison Group Mean=4.2).
    - Under the R21/R33 (Mean=2.2) and SBIR/STTR (Mean=2.1) funding mechanisms, grants from the IMAT program resulted in significantly more patent applications than the Comparison Group (R21/R33 applications Mean=1.6; SBIR/STTR applications Mean=1.3).
    - Grants from the IMAT program produced a similar number of patent awards to the Comparison Group, regardless of funding mechanism (overall IMAT patent awards Mean=2.3; overall Comparison Group patent award Mean=2.0).
3. Technology End Users found IMAT-developed technology to be valuable.
    - End Users represented a range of positions, including post-docs, researchers, and laboratory heads. End Users worked in labs that used the technology (30%), employed by institutes that used the technology (20%), or worked in a collaborative role with other researchers (25%). The remainder described technology-specific background and roles (25%).
    - End Users became aware of the technology through scientific publications (22%), employer use of the technology (22%), collaborations with other scientists (22%),

symposiums or conferences (17%), related work (11%), and through investor/startup companies (6%).

- Almost all End Users described the technology as either critical (48%), or very important (29%) to enhancing public health. Others (24%) described the importance of the technology to their specific field and other thoughts on the critical nature of the technology.
- The most common impacts on public health identified were increased technology efficiencies (28%), enhanced quality of research (20%), and advances in drug development (12%). The remainder of participants noted that they were unsure (12%) or it was too early to judge public health impacts (8%) but End Users thought that the technologies would have great potential to impact public health on a large scale (20%).

Table 1 provides a brief summary answer to each evaluation question. More details on each evaluation question are provided below the table.

Table 1. Evaluation Questions and Answers

Logic Model Area	Evaluation Question	Answer from Evaluation
1) Initial Investment	a) What were the pre-existing technologies that served as the basis for technology developed by IMAT?	In general, survey respondents identified pre-existing technologies that served as the basis for technology developed by IMAT, but some IMAT and non-IMAT funded grantees indicated there was no preceding technology.
	b) What technologies were proposed and what technologies were funded?	IMAT and non-IMAT grantees selected "Research Tools" to describe their technology or methodology. There were differences in secondary areas and in disease or research areas the two groups selected.
	a) How did the application process, FOA/solicitation, and IMAT funding structure (mechanisms) impact the development of the technology?	PD/PIs suggested the application process and the submission process were straightforward, clear, well thought-out, and well-suited to their goals and ideas, and that the review process was good or as expected.
	b) How were the technologies developed during the funding period for IMAT grantees?	Almost half of all PD/PIs interviewed described technology-specific advances made during the funding period, but challenges toward advancing technology were identified.

Logic Model Area	Evaluation Question	Answer from Evaluation
2) Program Activities	c) How did interactions with NIH, NCI, or other organizations impact the development of the technology for IMAT grantees?	In general, interacting with NIH both prior to and during the award period was beneficial for the majority of grantees who reported having such interactions.
	d) How did the research environment (e.g. institutional support; other related research activities) impact the development of the technology?	Both IMAT and Comparison Group grantees who sought institutional support during the patent application process found their institution helpful or very helpful. Additionally, PD/PIs felt working in a diverse and interdisciplinary work environment provided collaborative advantages that helped progress the research.
3) Short-, Medium-, and Long-term Outcomes	a) What was the development path after IMAT funding?	PIs with IMAT funded research intend to continue extending the technologies they developed using IMAT funds, particularly by obtaining patents and licenses.
	b) How were the details of the technology spread to scientific and/or clinical audiences?	Almost all IMAT grantees used traditional means to disseminate results. There were significant statistical differences noted indicating that IMAT funded researchers published more manuscripts with higher impact factors and a higher average number of citations than the Comparison Group researchers, and most of these differences were found when examining publications using the R21/R33 funding mechanisms.
3) Short-, Medium-, and Long-term Outcomes	c) To what extent and in what setting(s) is the technology or methodology being used?	IMAT grantees primarily identified genetics and proteomics research as a major use, and specific patient applications that included therapeutics, diagnosis, and disease-progression monitoring as ultimate uses. Grantees described End Users as scientists and clinicians in various public and private settings.
	d) Are there common themes for those grantees that did not achieve their aims within the IMAT funding period? If so, what are the themes?	IMAT grantees achieved marketability with their technology more than the Comparison Group. Of those IMAT grantees who did not achieve marketability, top reasons included research required more funding, results were not as expected, lacking knowledge or resources to achieve marketing stage.

Logic Model Area	Evaluation Question	Answer from Evaluation
	e) Did the short-term and medium-to-long-term outcomes differ from the Comparison Group? *Stage of Development*	There were no differences to note between IMAT or the Comparison Group, indicating that technology development may progress similarly by funding mechanisms regardless of whether the research was IMAT funded or not.
	Dissemination of technology via publications and patent	Grants within the IMAT program resulted in more publications and patent applications than the Comparison Group.
	Self-reported long-term impact	IMAT grantees reported the greatest area of impact as improving standards and methods for conducting cancer research and the Comparison Group reported advancement of the ability to treat as their greatest impact. Both groups reported improving the quality of biospecimens used in clinical management as their least impactful area.

Detailed Findings of Evaluation Questions

1) Initial Investment
   a) What were the pre-existing technologies that served as the basis for technology developed by IMAT?
      - Twenty-one (12%) of the survey respondents indicated there was no preceding technology or methodology for their idea. By comparison, 22% of the non-IMAT funded grantees in a Comparison Group indicated there was no preceding technology.
      - Survey respondents identified more than 250 pre-existing technologies that served as the basis for technology developed by IMAT.
   b) What technologies were proposed and what technologies were funded?
      - IMAT grantees predominantly selected two categories from a potential eight to describe their technology or methodology: “Research Tools” and “In Vitro and Ex Vivo Diagnostics.” The Comparison Group primarily described their research as “Research Tools” or “Small Molecules.”
      - From a list of 27 disease or research areas, IMAT grantees most frequently selected “Cancer,” “Translational Research,” “Genetics/Genomics,” “General Medical Sciences,” and “Biomedical Imaging and Bioengineering.” The Comparison Group most frequently selected “Cancer,” “Allergy, Autoimmune, and Infectious Diseases,” “Translational Research,” “Mental Health,” and “Biomedical Imaging and Bioengineering.”
2) Program Activities
   a) How did the application process, FOA/solicitation, and IMAT funding structure (mechanisms) impact the development of the technology?

- The majority of PD/PI comments suggested that the application process (n=53%) and the submission process (74%) were straightforward, clear, well thought-out, and well-suited to their goals and ideas.
- The majority of PD/PI comments (62%) described the review process as good or as expected. Almost all PD/PIs generally described the IMAT program as a good or great fit to help them meet or achieve their research goals.

b) How were the technologies developed during the funding period for IMAT grantees?
    - Almost half of all PD/PIs interviewed (46%) described technology-specific advances made during the funding period.
    - Twenty percent of PD/PIs interviewed described taking an iterative approach to advance the technology, while others described a strategy of approaching the technology development from multiple angles until they could arrive at a successful model or optimum results.
    - Challenges toward advancing the technology included time constraints, slow and laborious methods, and funding restrictions.

c) How did interactions with NIH, NCI, or other organizations impact the development of the technology for IMAT grantees?
    - In general, interacting with NIH both prior to and during the award period was beneficial for the majority of grantees who reported having such interactions and grantees appreciated the knowledge, support, and encouragement provided by IMAT program officers and staff.
    - Interactions generally resulted in improved research plans that either placed the proposed research in the context of the broader community, or narrowed the proposed research to ensure the end result (if successful) would be useful.
    - Specifically, the annual IMAT conference was perceived as a valuable opportunity to meet like-minded innovators and potential collaborators. It was also valued for stimulating fresh perspectives or new ideas and for providing opportunity to troubleshoot and gather feedback from respected peers.
    - A handful of IMAT grantees explained that one of the overall benefits of the program was its capacity to continue fostering a community of innovative biomedical researchers.
    - Learning about alternative funding sources was also an important outcome for a small portion of grantees.

d) How did the research environment (e.g. institutional support; other related research activities) impact the development of the technology?
    - Both IMAT and Comparison Group grantees who turned to their institutions for support during the patent application process found their institution helpful or very helpful.
    - PD/PIs who were interviewed reported strong institutional support via resources to complete the IMAT research. Resources most commonly reported included additional funding, provision of critical equipment, appropriate infrastructure, and provision of personnel to assist with supplemental work.
    - PD/PIs noted that working in close proximity to colleagues from diverse interdisciplinary backgrounds provided collaborative advantages that helped progress the research.

3) Short-, Medium-, and Long-Term Outcomes
   a) What was the development path after IMAT funding?
      - PD/PIs with IMAT funded research intended to continue extending the technologies they develop using IMAT funds, particularly by obtaining patents and licenses.
      - More than half of grantees reported their research had led to marketable technology or widely accepted methodology.
      - Forty percent reported that additional technologies or methods have been developed as a result or extension of the results of the IMAT grant.
        - Further development of work often included patents, licensing, international or Food and Drug Administration (FDA) approval, and clinical trials.
        - By far, the most common developmental pursuit included obtaining a patent followed by licensing (8.4%).
        - FDA approval was the least common (with 31.5% indicating "Not applicable").
      - PD/PIs were likely to pursue research with an intended outcome of obtaining a license or a patent
        - 63% of IMAT grantees who were surveyed indicated that they did *not* intend to engage in clinical trials, 68% did *not* intend to seek FDA approval, 59% did *not* intend to seek international approval, 36% did *not* intend to obtain a license, and 24% did *not* intend to obtain a patent.
   b) How were the details of the technology spread to scientific and/or clinical audiences?
      - Almost all IMAT grantees used traditional means to disseminate results and the vast majority presented findings at scientific meetings or conferences, gave seminars, and wrote papers and publications.
      - A large portion of grantees presented to clinical audiences.
      - Almost a third (31%) established spin-off companies.
      - Grants within the IMAT program have produced a large number of publications and patents, with 2,054 manuscripts published and 361 patent applications/awards made between 1999 and 2013.
      - There were significant statistical differences indicating that IMAT funded researchers published more manuscripts with higher impact factors and a higher average number of citations than the Comparison Group researchers, and most of these differences were found when examining publications using the R21/R33 funding mechanisms.
   c) To what extent and in what setting(s) is the technology or methodology being used?
      - Most (46%) of the major uses identified by IMAT grantees involved research (mostly genetics and proteomics), but when describing ultimate uses, grantees also named specific patient applications that included therapeutics, diagnosis, and disease-progression monitoring.
      - Grantees described End Users as scientists, clinicians (primarily oncologists and pathologists), individuals working in clinical labs, and private sector scientists working for pharmaceutical, biotech, and/or diagnostics companies.
   d) Are there common themes for those grantees that did not achieve their aims within the IMAT funding period? If so, what are the themes?
      - More than half of surveyed IMAT grantees reported that their technology had achieved marketability or wide acceptance compared to 41% of the Comparison Group.

e) Did the short-term and medium-to-long-term outcomes differ from the Comparison Group?
    - Stages of development: There were no differences to note in stage of development between IMAT or the Comparison Group, indicating that technology development may progress similarly by funding mechanisms regardless of whether the research was IMAT funded or not. Responses were evenly distributed across time points and across stages of development as would be expected for the type of funding mechanism.
    - Dissemination of technology via publications and patents: Overall, the IMAT funded grants have resulted in significantly more patents (37.9 compared to 30.1) and publications (534.2 compared to 303.7) per $100,000,000 than the Comparison Group. The Comparison Group had a lower percentage of grants resulting in publications (50.3%) than the IMAT group (63.4%), and the Comparison Group had a lower percentage of grants resulting in patent applications or awards (10%) than the IMAT group (21.8%).
    - Self-reported long-term impact: The IMAT group's greatest area of impact was improving standards and methods for conducting cancer research and the Comparison Group's greatest area of impact was the advancement of the ability to treat. Both groups reported little impact on improving the quality of BIOS used in clinical management.

Conclusions

Overall, the results of this evaluation suggest that IMAT is an essential and productive program within NCI. Maintenance of the IMAT program will ensure that cutting-edge, state-of-the-art research will continue to advance cancer research to the ultimate benefit of technology End Users, which includes clinicians, researchers, and patients.

Some themes emerged throughout the evaluation process that might be useful to consider for possible future iterations of the IMAT program. First, IMAT staff should continue the extensive, responsive communication with PD/PIs, as most participants described such communication as instrumental in progressing the research. Second, although the annual PI meeting was positively received, PD/PIs suggested that PI meetings should be enhanced to include a wider variety of presentations, expansion of attendee types, more time for interactions between participants, and meeting-follow-up activities. Third, PD/PIs suggested that NCI provide additional resources to help with technology commercialization (e.g., workshops) to further the technology dissemination after the grant period ended. Finally, participants suggested that the IMAT program should be marketed and expanded to encourage more applications and appeal to those who are unaware of the program.

Recommendations for the IMAT Program

Throughout the process of completing the evaluation, some themes emerged that might be useful to consider for possible future iterations of the IMAT program.

- IMAT staff should continue the extensive, responsive communication with PD/PIs
- PI meetings should be enhanced to include a wider variety of presentations, expansion of attendee types, more time for interactions between participants, and meeting-follow-up activities
- NCI should provide additional resources to help with technology commercialization (e.g., workshops)

- The SBIR/STTR funding mechanisms are associated with more patents than the R21/R33 mechanisms indicating that there is value in this different approach to high risk research
- The biospecimen (BIOSP) thematic area fulfills a specific niche because PD/PIs with these grants report the highest impact in the area of improving the utility of biospecimens in research while PD/PIs with other grants consider biospecimen research to be their area of least impact
- NCI should consider re-introducing coupled awards in a limited way to meet the needs of individual projects that may benefit from a coupled approach

Recommendations for Future Evaluations

In order to improve future evaluation and monitoring of the outcomes of the IMAT program, Ripple Effect observed several areas that could improve data collection efforts in the future and potentially become embedded within program reporting.

- Asking PD/PIs to include the formal and alternative names of their technologies in the progress reports (in a semi-structured field) to aid future evaluations
- Asking PD/PIs to include downstream development (licensing, adoption by others) in as standardized a fashion as possible in annual reporting
- Incorporating the stages of technology development in annual reporting (or as a supplemental report that could be used for regular program monitoring/final reporting)
- Encouraging grantees to consistently use NIH's RePORTER to obtain more data on fields such as number of text mentions for "news" and "media" or number of press releases and "Research Matters" submissions
- Exploring the potential to quantify measures of risk for future awards to explore differences, perhaps within the review process
- Continuing to use certain survey items to more consistently measure "progress" across grantees
- Continuing to use the Comparison Group strategy to add richness and rigor for evaluations
- Continuing to use End User interviews to identify successes, challenges, and impact from external sources
- Incorporating known, or potential End User contacts as a standardized question in the progress reports (in a semi-structured field) to aid future evaluations and help improve End User recruitment

Outline of Report

This document is a summative report of the comprehensive evaluation of the IMAT program. For this comprehensive evaluation, we focused on gathering quantitative and qualitative data for as many IMAT grants as possible. For the benefit of readers who prefer a case study approach to better place results in context, we have included a selection of case study evaluations in Appendix C.

This report is divided into five main sections.

1. The Introduction describes the history of the Innovative Molecular Analyses Technology (IMAT) program and its value to cancer research.

2. Evaluation Design and Methodology describes the evaluation questions along with the methods used to answer the evaluation questions.
3. The Findings section describes the results of the analysis and answers the evaluation questions and is divided into four main parts, which correspond to the logic model: 1) initial investment, 2) program activities, 3) program outputs, and 4) short-term and long-term outcomes.
4. The Conclusions section summarizes the overall findings and the impact of the IMAT program.
5. Recommendations for the continued success of the IMAT program and recommendations for future successful evaluations are also detailed.

Finally, there are 12 appendices that provide supplemental information to the content of the report. Appendix A includes all references used to gather background information. Appendix B describes the IMAT program. Appendix C details case studies for selected grantees. Appendix D describes the history of past IMAT evaluations. Appendices E and F detail the FOAs included in the IMAT and Comparison Groups. Appendices G and H detail the archival data collection methods and data collection instruments. Appendices I and J list the institutions and organizations with IMAT awards as well as principal investigators with IMAT awards. Appendix K describes preceding technologies, and Appendix L describes funded technologies and methodologies. Appendix M provides a list of abbreviations used throughout the report.

Throughout the report, graphs generally follow a blue and orange color scheme. However, when displaying IMAT group and Comparison Group differences, the IMAT group is represented in blue and the Comparison Group is represented in green.

Introduction

The National Institutes of Health (NIH) is committed to applying knowledge of living systems to enhance health, lengthen life, and reduce illness and disability (NIH, 2013a). Innovative ideas and research often hold great promise to transform biomedical research and the practice of medicine; however, such research can be riskier, too novel, or at too early a stage to fare well in the traditional peer review process compared with more traditional investigations.

Selected Trans-NIH Programs Support Innovation

Recognizing the importance of innovation and its potential to accelerate the pace of discovery in biomedicine, NIH, as well as its individual Institutes and Centers (ICs), encourages and supports pioneering biomedical research through various grant programs. NIH's Common Fund was established in 2006 to support cross-cutting, trans-NIH programs and has been used to support a number of high impact programs (NIH, 2015a). The High-Risk, High-Reward Research Program (NIH, 2015b), which is funded through the Common Fund, contains three award types, covering all career stages, that encourage creative thinkers to pursue exciting and innovative ideas in biomedical research: the NIH Director's Pioneer, New Innovator, and Transformative Research Awards. The application and review criteria for these awards differ from traditional grants in that they may not require preliminary data or detailed annual budgets and because they emphasize innovation, creativity, and the potential for significant impact within biomedicine or behavioral science. Additionally, the NIH Exploratory/ Developmental Research Grant Award (R21) mechanism, in which ICs participate directly or through their own specific funding opportunity announcements (FOAs), encourages exploratory and developmental research by providing support for early and conceptual stages of project development (NIH, 2013b). The Exploratory/Developmental Grants Phase II (R33) mechanism can provide follow-on funding for a second phase of support; R33 awards can be coupled with or be independent from R21 awards.

NIH also provides support for small companies in the United States involved in biomedical research and development (R&D). Through individual ICs, NIH's Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs, created in 1982 and 1992, respectively, provide early-stage capital to small businesses to help them engage in Federal R&D that has a strong potential for commercialization (NIH, 2015c). The grants are intended to stimulate technological innovation in the private sector.

Technology Development and the National Cancer Institute

Individual ICs also encourage and support innovative research with their own programs. The National Cancer Institute (NCI) has a variety of funding opportunities designed to support imaginative research aimed at improving the prevention, detection, diagnosis, and treatment of all forms of cancer. For example, NCI's Alliance for Nanotechnology in Cancer initiative is engaged in efforts to harness the power of nanotechnology to radically change the way cancer is diagnosed and treated, and its goals include developing both new research tools to identify biological targets and novel methods to manage symptoms (NCI, n.d.a). Within this alliance, the Innovative Research in Cancer Nanotechnology Award utilizes the U01 funding mechanism to provide researchers with funds to develop innovative, multi-disciplinary research projects in cancer nanotechnology (NIH, 2014).

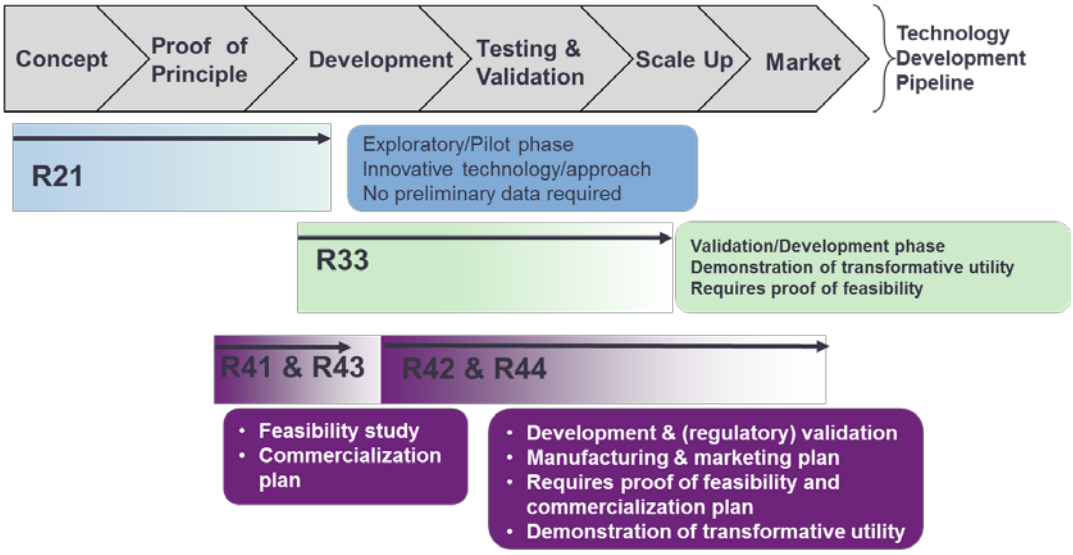
NCI also utilizes the R21 mechanism to support innovative research. For example, within the Informatics Technology for Cancer Research (ITCR) initiative, the Development of Innovative Informatics Methods

and Algorithms for Cancer Research and Management R21 Award funds projects that address needs across the cancer research continuum (NIH, 2015d), and review criteria emphasizing novelty. NCI's Cancer Imaging Program (CIP), which was originally started in 1996 as the Diagnostic Imaging Program, administers grants in four areas which, overall, support *in vivo* medical imaging sciences in basic and applied research (NCI, n.d.b). This program's awards support clinical trials, research that accelerates the translation of targeted technologies, and innovative research focused on image-guided drug delivery (NCI, n.d.c).

The National Cancer Institute (NCI) launched the Innovative Molecular Analysis Technologies (IMAT) program in 1998 to support the development of highly innovative technologies to advance cancer research and clinical care capabilities, with an ultimate goal of bringing the technologies into development to benefit researchers, clinicians, and cancer-relevant communities and patients.

IMAT program support has been focused on the technology development pipeline as shown in Figure 1. Throughout its history, the IMAT program has used the R21 and R33 mechanisms (activity codes) as well the SBIR (R42 and R44) and STTR (R41 and R43) mechanisms. Simplistically, although the mechanisms of support are different, these support mechanisms can be thought of as consisting of two phases: an initial phase of either the R21, R41, or R43, followed by the R33, R42, or R44. At times the phases have been coupled; at other times the support has been uncoupled. Appendix B – The IMAT Program contains more details on the IMAT Program.

Figure 1 IMAT Program Support in the Context of the Technology Development Pipeline



Purpose of the Current Evaluation

NCI commissioned a comprehensive and rigorous evaluation to assess the process and outcomes of the IMAT program, and to identify opportunities for NCI to improve the program's utility for the broad continuum of cancer researchers, clinicians, and ultimately, patients. The focus of the evaluation was on understanding the successes of supported technologies. Ripple Effect Communications, Inc. (Ripple Effect) has conducted a comprehensive process and outcome evaluation of the IMAT program under contract HHSN263200800077B.

The evaluation project was conducted in two phases. This evaluation report presents the evaluation design, methodology, and findings from both phases of the project. The first phase, which took place

from September 2014 through October 2015, focused on the collection and analysis of archival data as well as the administration and analysis of a web-based survey and telephone interviews. The second phase, which took place from November 2015 through July 2016, focused on the collection and analysis of telephone interviews of technology End Users.

One of the goals of the evaluation was to provide sufficient documentation (e.g., field structure, data relationship structure, and query process) to allow NCI to repeat the evaluation process in the future without having to recreate or revisit previous efforts. To that end, Ripple Effect dedicated Phase I resources to building a linked database within the Center for Strategic Scientific Initiative's (CSSI) existing SharePoint infrastructure, along with supporting documentation and guides, to facilitate data quality checks and future internal evaluation efforts.

Through a multi-faceted approach to data collection and analysis, this evaluation will also contribute to the NIH's charge to the Scientific Management Review Board to better "capture and communicate the value of biomedical research supported by NIH" (Dodson, 2016).

Evaluation Design and Methodology

The evaluation efforts were overseen by a trans-NIH Evaluation Advisory Committee (EAC) composed of Federal officers and evaluation specialists. The composition of the EAC was as follows:

- Anthony (Tony) Dickherber, PhD, Program Director, IMAT, National Cancer Institute
- Richard Conroy, PhD, Director, Division of Applied Science & Technology, National Institute of Biomedical Imaging and Bioengineering
- Fred Friedman, PhD, Program Director, National Institute of Mental Health
- Madelon Halula, PhD, Initiative Coordinator, National Institute of Allergies and Infectious Diseases Division of Acquired Immunodeficiency Syndrome (AIDS)
- Elizabeth Hsu, PhD, Senior Health Science Analyst, National Cancer Institute
- Michael Smith, PhD, Program Director, National Human Genome Research Institute

The Ripple Effect team developed a mixed-methods evaluation design to inform the key evaluation questions for this project. Ripple Effect's evaluation experts relied on existing documentation (e.g., past evaluations, previous and current FOAs), conversations with NCI program officers, the trans-NIH EAC, and an external subject matter expert (SME) panel to inform the evaluation design and methodology. This SME panel was comprised of three members:

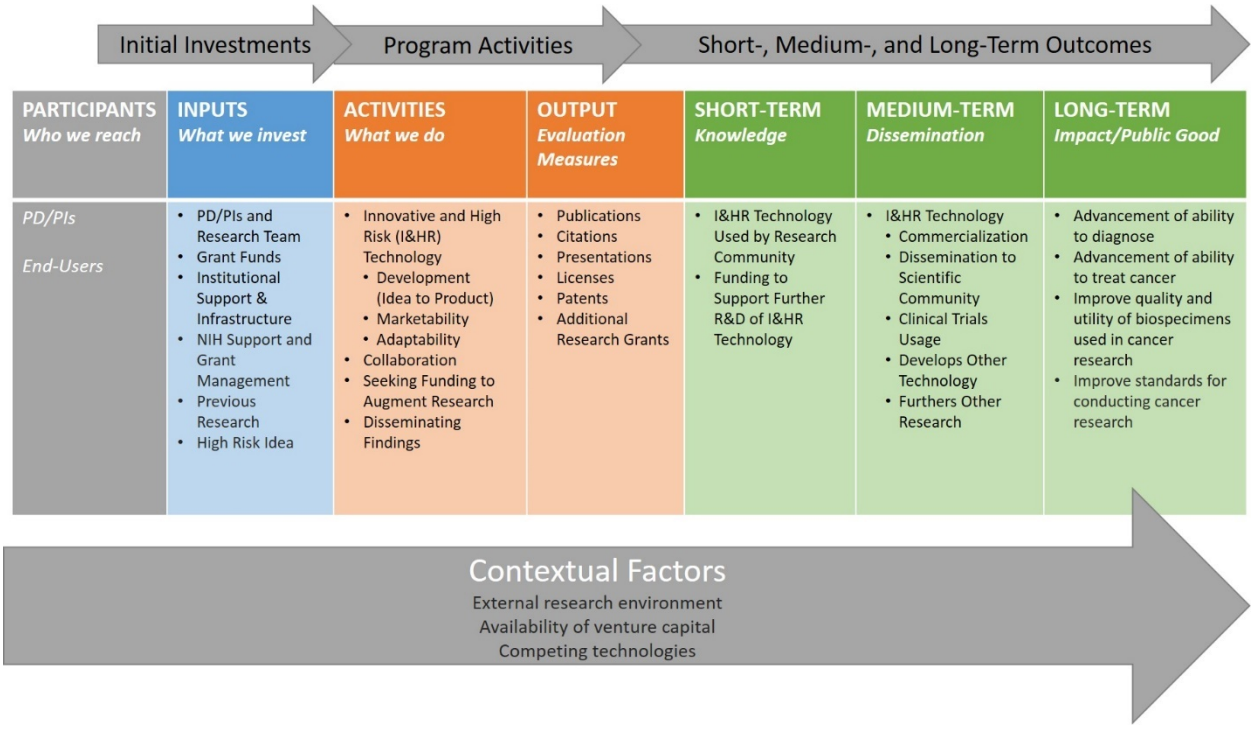
- Mike Marron, PhD, a retired NIH program officer, former Division Director for Biomedical Technology Division of National Center for Research Resources (NCRR)
- Maureen Mulvihill, PhD, an expert from the small business community, President and Chief Executive Officer (CEO) of Actuated Medical
- Brian Zuckerman, PhD, an evaluation expert in technology development, Research Staff Member of the IDA Science and Technology Policy Institute (STPI)

This evaluation used primary data collection mechanisms, including a web-based survey and telephone interviews[1], and secondary data collection sources (e.g., IMPAC II, United States Patent and Trademark Office (USPTO)[2]) to inform the evaluation. This blend of quantitative and qualitative sources allows the evaluation team to have both standardized information to compare data on IMAT grantees to a Comparison Group (described later) as well as nuanced contextual data to yield a richer picture and understanding of the process and outcomes of the IMAT evaluation.

Conceptual Framework

This evaluation was guided by the IMAT program logic model used for the 2007 Feasibility Study for Outcome Evaluation, with modifications based on Ripple Effect input and discussions with the Program Director, Dr. Anthony (Tony) Dickherber. The current conceptual framework for the IMAT program is presented in Figure 2.

Figure 2. IMAT Outcome Evaluation Conceptual Framework/Logic Model



This logic model specifies the key participants and inputs into the IMAT program. The model outlines the major IMAT activities and outputs, highlighting unique attributes such as the high risk/high reward nature of the program. Finally, the model details short-, medium- and long-term outcomes, helping to articulate the intended outcomes of the IMAT program. This model also incorporates contextual factors that can affect the intended pathway to outcomes. For example, throughout the time of the IMAT

[1] Survey and interview protocols and instruments were reviewed by the Office of Human Subjects Research (Protocol #12656) and determined to be excluded from institutional review board (IRB) review. Data collection was approved by the Office of Management and Budget (OMB) under OMB control number 0925-0720.

[2] Note that iEdison was considered as a data source but the evaluation team found the USPTO data source to be more amenable for reasons related to data access and data completeness.

program, the external research environment changed. Success rates for research project grants funded by NCI in 1998 were 33%, while in 2013 they were 14% (NIH RePORT, 2012). In addition, since the inception of the IMAT program in 1998, the program has evolved to meet the needs of program participants. Accounting for contextual change in an exact manner over time will be difficult; however, the process of drawing conclusions regarding the overall program will consider these and other relevant contextual factors. Changes to funding levels and mechanisms of support will also have to be considered in the evaluation of the overall program.

The Ripple Effect evaluation team identified a set of key evaluation questions to focus the evaluation. The evaluation questions are presented in Table 2 along with the respective major data source.

Table 2. Evaluation Questions and Relevant Data Source

Logic Model Area	Evaluation Question	Archival Data	Web-based Survey	Interview
Initial Investment	What were the pre-existing technologies that served as the basis for technology developed by IMAT?		◆	◆
	What technologies were proposed and what technologies were funded?	◆	◆	
Program Activities	How did the application process, FOA/solicitation, and IMAT funding structure (mechanisms) impact the development of the technology?			◆
	How were the technologies developed during the funding period for IMAT grantees?			◆
	How did interactions with NIH, NCI, or other organizations impact the development of the technology for IMAT grantees?		◆	◆
	How did the research environment (e.g. institutional support; other related research activities) impact the development of the technology?		◆	◆
Short-, Medium-, and Long-term Outcomes	What was the technology development path after IMAT funding?	◆	◆	◆
	How were the details of the technology spread to scientific and/or clinical audiences?		◆	◆
	To what extent and in what setting(s) is the technology or methodology being used?		◆	◆
	Are there common themes for those grantees that did not achieve their aims within the IMAT funding period? If so, what are the themes?		◆	

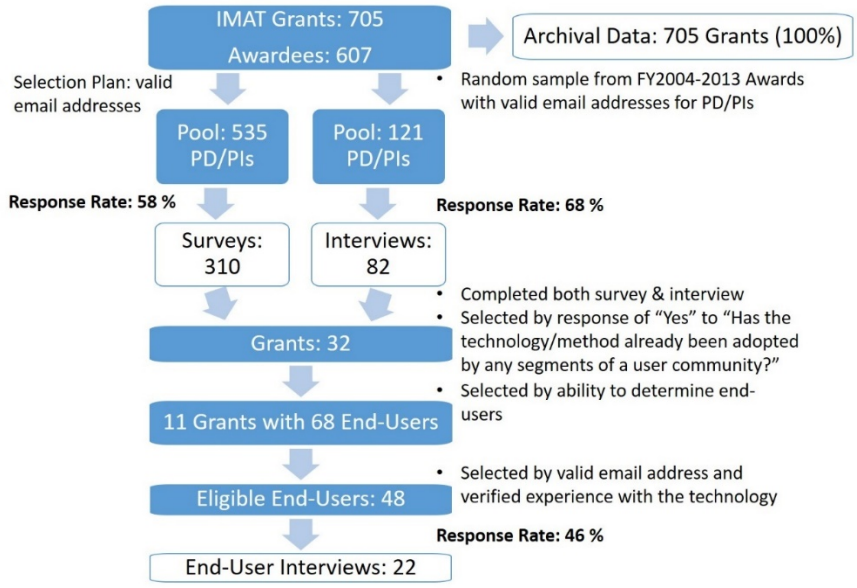
Logic Model Area	Evaluation Question	Archival Data	Web-based Survey	Interview
	Did the short-term and medium-to-long-term outcomes differ from the Comparison Group? *Stage of Development*		◆	
	Dissemination of technology via publications and patent	◆		
	Self-reported long-term impact		◆	

IMAT Group Selection Process

The study design provided for several data sources of IMAT grant and grantee information: archival data, web-based surveys, phone interviews with Program Directors/Principal Investigators (PD/PIs), and phone interviews with Technology End Users. Every IMAT recipient from 1998 to 2013 was included in the evaluation as part of the IMAT grant. During the time period covered by the evaluation, the IMAT program has issued 540 R21 and R33[3] awards and 165 SBIR and STTR awards, supporting approximately 500 unique technology platforms and more than 500 PD/PIs. There were no SBIR/STTR IMAT awards in 2012 or 2013. See Appendix C for case studies of selected grantees.

The selection and sampling plan for each of the data sources is shown in Figure 3.

Figure 3. Summary of IMAT Grants, Data Collection Sources, and Number of Collection Points

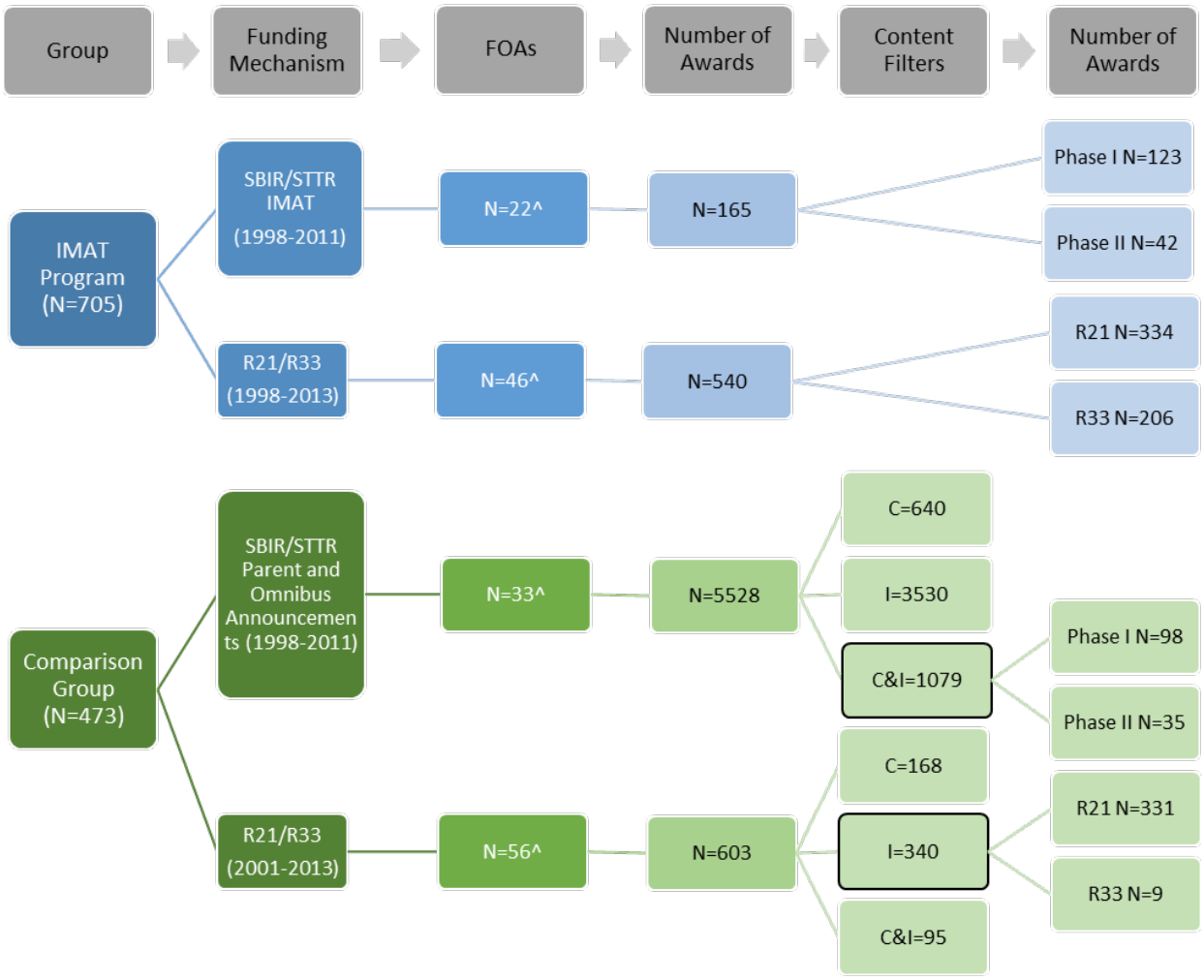


[3] The IMAT coupled grant was an initial two-year R21 award, which converted to an R33 upon completion of the specified aims, as determined by a Program Officer. In fiscal year (FY) 2007 (FY2007), NIH decided to move to a competitive award process for follow-on grants and the awarding of coupled IMAT grants was ended. IMAT awarded 110 coupled grants. For the purposes of this evaluation, each activity mechanism, even if coupled, was treated as a distinct award, resulting in 219 distinct awards that were coupled.

Comparison Group Selection Process

A Comparison Group is critical to appropriately evaluate and contextualize IMAT program outcomes. Various Comparison Group options were considered, including the use of unsuccessful IMAT applicants. Based on feedback from the EAC and the SME panel, as well as other design considerations, the evaluation team decided to use successful applicants pooled from similar NIH FOAs over the same time period as IMAT. Pooling successful grantees from similar technology development-focused NIH FOAs has the advantage of comparing the IMAT program directly against other successful grants in similar NIH programs. Figure 4 illustrates this selection process.

Figure 4. Comparison Group Selection Process



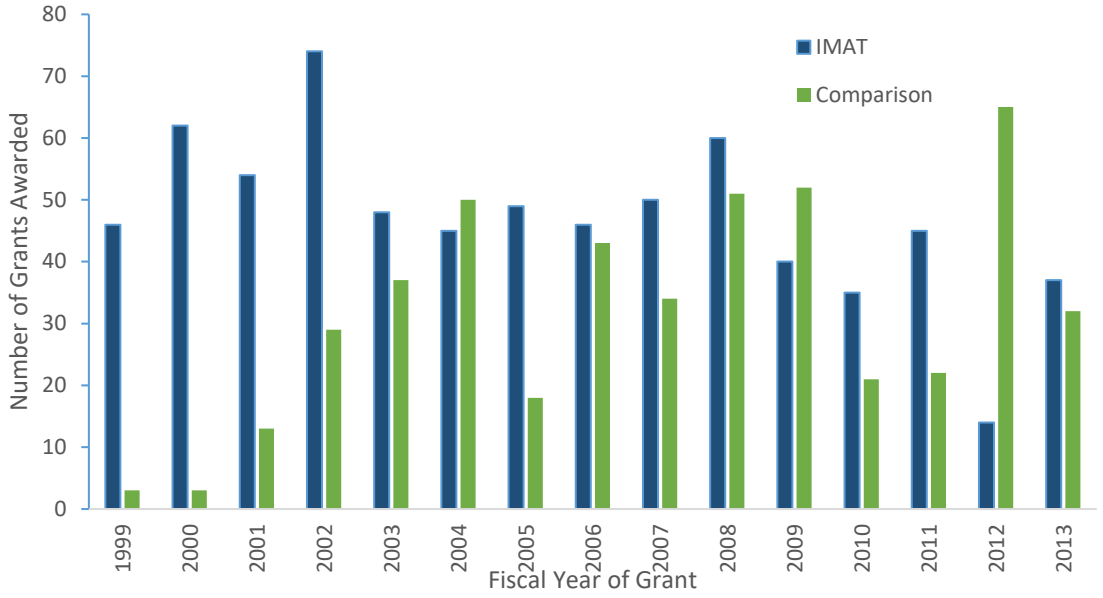
Note: C=Cancer; I=Innovation; C&I=Cancer AND Innovation

^Note all FOAs are included in the final sample. A detailed list of all IMAT and Comparison Group FOAs can be found in Appendix E.

Because the IMAT program is a technology[4] development initiative, the first step to create the Comparison Group was to identity FOAs focused on technology during the time period of the IMAT awards (FY1999 to FY2013) by activity code. All awards stemming from these FOAs were examined. Awards that had the same activity code as IMAT awards (i.e., R21, R33, R41, R42, R43, and R44) were gathered, resulting in an initial pool of 6,131 potential awards for the Comparison Group. Content filters were subsequently applied and focused on the two main terms of "Innovate" (including variations on "innovate" such as "innovation" and "novel") and "Cancer" (including terms "cancer," "onco," "tumor," "malignancy," "carcinoma," and "leukemia") for both R21/R33 awardees and SBIR/STTR awards.[5] Among R21/R33 awardees, only 95 awards had positive hits for both "Innovate" and "Cancer." To expand this pool to be proportional to the number of IMAT awardees in the R21/R33 category, a sole content filter for "Innovate" was used. There were many results using both content filters among the SBIR/STTR awards, so the initial threshold for inclusion included keywords related to both "Innovate" AND "Cancer." The resulting pool for the Comparison Group was 1,079.

The available pool of 1,079 was disaggregated by fiscal year and activity code/phase (e.g., R41 and R43 as Phase I and R42 and R44 as Phase II). Next, the number of awardees in each group was compared to the number of IMAT awardees again. For years when the number of awardees from the Comparison Group was less than the number of IMAT awardees, all Comparison Group awardees were selected to be part of the sample. For those years where the number of Comparison Group pool awardees exceeded the number of IMAT awardees, the study team randomly generated numbers, ranked these numbers within year, and then selected the equal number of IMAT awardees, oversampling 15% to account for potential non-response from Comparison Group awardees.

Figure 5. Number of Grants Awarded to IMAT and Comparison Groups



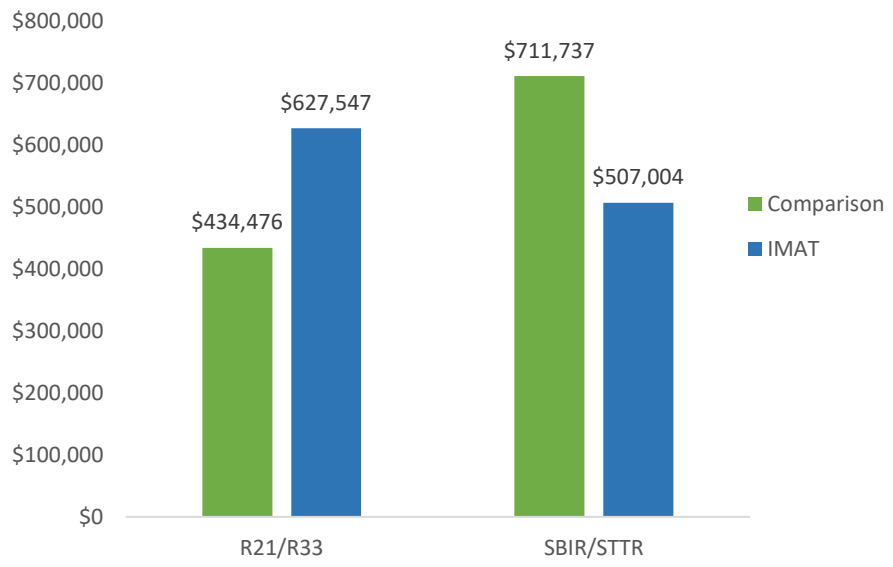
[4] The IMAT program defines technology as "instruments, devices, platforms, tools and associated techniques or methods."

[5] A content filter was applied using the term "technology," however the number of awards using that term in the aims was too small to create a meaningful Comparison Group.

A comparison of the number of grants awarded for the IMAT group and the Comparison Group from FY1999 to FY2013 shows that representation across fiscal years is not consistent (Figure 5). This inconsistency is due to differences in the use of different funding mechanisms in the study time period (e.g., the lack of SBIR/STTR awards for IMAT grantees in FY2012 or FY2013, the lack of technology focused R21/R33 FOAs in the Comparison Group from 1998-2000, and the fact that NIH does not frequently use the R33 mechanism).

The Comparison Group was awarded $242,382,652 during fiscal years 1999 to 2013 and received 473 awards, for which the average amount was $512,437 per grant awarded. In comparison, the IMAT group was awarded $422,531,335 and received 705 awards for the same time period, for which the average amount was $599,335 per grant awarded. Figure 6 presents a depiction of the funding dollar amounts awarded to the IMAT and Comparison Groups by funding mechanism. The higher amount of funds awarded under the R21/R33 funding mechanisms in the IMAT program likely reflects differences between IC uses of this mechanism, compared to the more standardized use of the SBIR/STTR funding mechanisms across the NIH. For example, IMAT may have used the R33 award more frequently than other ICs and their programs, the IMAT program funded R21 awards at a higher amount than the NIH standard beginning in 2008, and the IMAT program encouraged a strong emphasis on aggressive scientific advancement.

Figure 6. Average Dollar Amount Awarded to IMAT and Comparison Groups by Funding Mechanism



Comparison Group Limitations

To strengthen the rigor of this evaluation, we desired to use a comparison group of PD/PIs who had similar attributes and characteristics as the IMAT group defined by grant status.

The evaluation team had many internal discussions about the selection of a Comparison Group for this evaluation effort. As a result of these discussions, Ripple Effect put forward two options for discussion with the Expert Panel and the EAC. These two options are described below. With input from these sources, the evaluation proceeded with the Comparison Group selection as described in the previous section. All parties involved in the discussion and decision of the Comparison Group recognized that the final Comparison Group was the best selection given the possible choices available. The Comparison

Group should be appreciated for the value that it can bring (providing a relevant benchmark for conclusions) albeit the imperfect nature of the Comparison.

Table 3 Considerations for Comparison Group Selection

Option	1: Unsuccessful IMAT applicants	2. Awardees of Similar NIH Programs
Perspective	Unsuccessful	Successful
IC	NCI only	NCI and others
Activity Codes	SBIR/STTR & R21/R33	Need to limit to SBIR/STTR & R21/R33 for comparison purposes
Cancer-relevance	Yes	Maybe
Technology-relevance	Yes	Maybe
Multi-disciplinary	Yes	Maybe
Trans-divisional	Yes	Maybe
Commitment to NI/ESI	Yes	Maybe
Unique review structure and process	Yes	Maybe
Pros	- Closest match to the program goals, years, activity code, etc. - Finding unfunded applicants who brought their technology to market could question the need for IMAT (showing truly unbiased evaluation protocol) - Results could provide best practices to advance technology with limited funding support	- Unsuccessful applicants would not be expected to disseminate successful technologies - Use of multiple programs avoids negative of "finger-pointing" results that could result from a 1:1 comparison against another NIH program
Cons	- Unsuccessful applicants would not be expected to bring technology to market - Interview questions may not relevant (esp. outcome)	- Non-match to the program goals - Interview questions may not be relevant

End User Selection Process

End Users are those researchers who use a product, technology, or other innovation that resulted from IMAT funding. The evaluation sought to sample these End Users whose external perspective provided important insight to determine the extent of use and value of the associated technologies beyond the grantees and extending to the public good.

Of the total IMAT grants, the pool of grants to be considered for potential End Users was limited to those technologies/methodologies that were randomly selected for, and participated in the PI interviews (n=82). This pool was then narrowed to those PD/PIs that also completed the survey (n=71). Finally, we used the response to a question from the PD/PI survey to focus on those grants in which the

technologies had been adopted by any segment of a user community (n=32).[6] Table 4 provides details on the number of awards for End User interview consideration by fiscal year of the award.

Table 4. Number of Awards for End User Interview Consideration by Fiscal Year

Fiscal Year	Number of Awards for End User Interview Consideration
2004	2
2005	2
2007	7
2008	3
2009	4
2010	4
2011	2
2012	2
2013	6
Total	**32**

The interview plan assumed 20-30 End User interviews, ideally spread across several technologies, with five to seven interviews per grant/technology. To determine the order of selection among the 32 technologies, the evaluation team assigned random numbers to each technology type. Based on the ranking, the technologies were analyzed for possible End Users by reviewing progress reports and publications (see more details below). The identified End Users were contacted for participation in a phone interview. After limited success reaching End Users from the initial eight technologies, the process was repeated, considering all 32 technologies in the sample. As a final result, there were 23[7] participants from 11 grant technologies. Although the final set of awards reflected a range of years (FY2004 to FY2013) as well as technology types (i.e., Research Tools; In Vitro and Ex Vivo Diagnostics; Cancer Modeling; Drug Delivery/Targeting/Screening, High-Throughput Screening, Imaging Tools or Contrast Agents, Sample Preparation or Processing; Sample Preservation and/or Sample Quality Assessment), none of the selected awards corresponded to the most well-known technology successes. Appendix L – Funded Technologies and Methodologies contains the trademarked or formally designated names of the technologies or methodologies funded under the IMAT grant.

The grants that produced the technologies selected for the End User interviews were as follows:

- Cancer Detection Technology *(R42CA108247-01 / FY2004)*
- Development of an Automated Frozen Sample Aliquotter (*R21CA114167-01 / FY2005*)

[6] "Has the technology/method already been adopted by any segments of a user community (e.g., clinical, research)?"

[7] Twenty-three End Users responded and participated in the interview. One End User was later deemed ineligible and the interview was not analyzed.

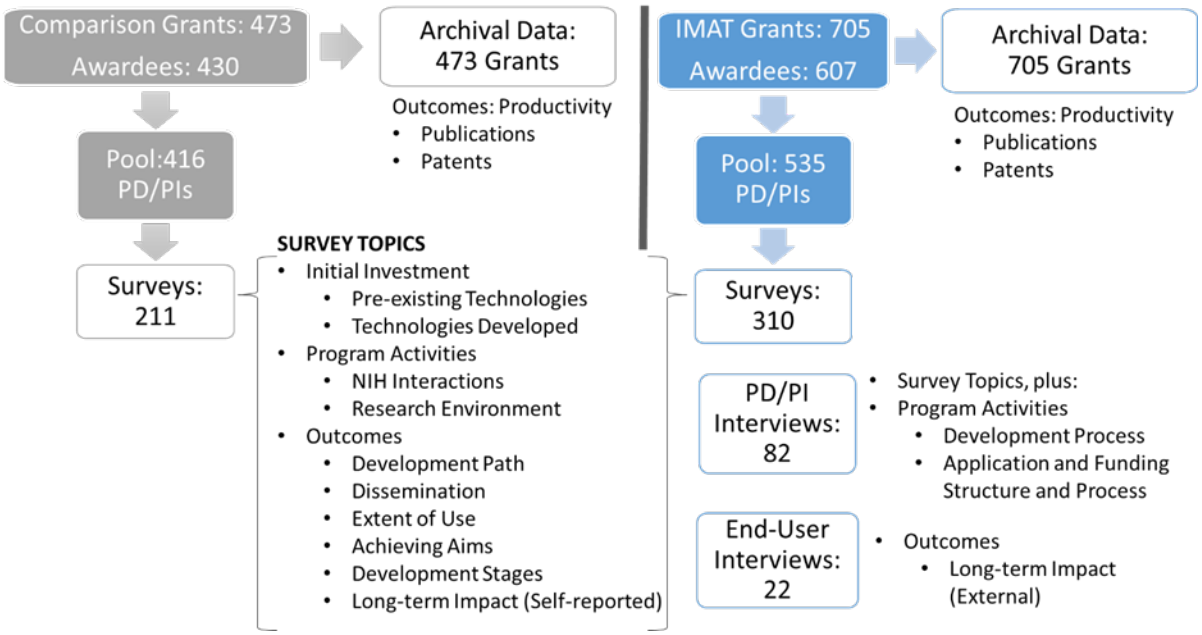
- Technology for Sensitive and Reliable Mutational Profiling in Pancreatic Cancer (*R21CA138280-01 / FY2009*)
- Transfected cell arrays for cancer research (*R21CA125285-01 / FY2007*)
- Surrogate and Sentinal Technologies to Monitor Stability of Cancer Phosphoprotein (*R21CA125698-01A1 / FY2008*)
- VEC3-Valve Enabled Cell Co-Culture Platforms for Cancer Biology Study (*R21CA155572-01A1 / FY2011*)
- Microfluidic 3D Assays for Metastatic Cancer (*R33CA174550-01 / 2013*)
- Microfluidic Channels for High Density, High Performance Culture Assays (*R21CA122672 / FY2007*)
- Application of Technologies for Interactome Network Analyses of Cancer Mutations (*R33CA132073-01 / FY2008*)
- Multiplexed Reiterative Immunofluorescence Analyses via Engineered DNA Circuitry (*R21CA147912-01 / FY2010*)
- Emerging Technologies Applied to the Discovery of Human Tumor Viruses (*R33CA120726-01A1 / FY2007*)

To select End Users for each technology, survey findings and interview notes from PI interviews were reviewed to identify any named End Users. Literature citing the initial publication of the IMAT technology was reviewed to identify names of additional End Users. This process included a review of the literature by the Program Officer to help distinguish "use" of the technology.

Data Collection Sources

Multiple data sources were used to gather data, insights, and perspectives into different facets of the IMAT program outcomes. This section provides an overview of the various data sources used to answer the evaluation questions, also shown in Figure 7.

Figure 7. Sources for Collecting Data on Evaluation Questions



Archival Data

The evaluation team compiled secondary data on IMAT's application and grant history from NIH databases (IMPAC II, NIH Guide for Grants and Contracts). In addition, the evaluation team leveraged other secondary data sources, such as the US Patent and Trademark Office (USPTO) and PubMed to obtain patent and publication data. This approach reduced burden on respondents to self-report and standardized the information received across IMAT and Comparison Group grantees because the same data was collected. This method was particularly effective given the length of time the IMAT program has been in existence such that our data collection method did not rely on memory.

All archival data described in this section is collected and available on the NCI IMAT username and password-protected SharePoint site at https://cssiod.sharepoint.nih.gov/IMAT/IMAT_Eval/SitePages/Home.aspx. The queries used to collect the data and links as part of the SharePoint databases are provided in Appendix G.

IMPAC II. The evaluation team obtained a list of all FOA numbers released by the IMAT program from the IMAT Program Officer. In addition, the team performed independent searches on the NIH Guide for Grants and Contracts database. The team documented information about each FOA, including the dates that the FOAs were posted, application due dates, the thematic area (IMAT-themed, EMAT-themed, or BIOSP-themed) addressed by the FOA, and a hyperlink to the online FOA. Information on all applications submitted to the IMAT program was obtained by querying the IMPAC II database. To obtain the list of IMAT awards, the team filtered the applications list to include only applications that had a successful award status. A list of institutions that applied to the IMAT program was obtained by extracting the list of External Organization IDs from the IMAT applications data. Similarly, the team obtained a list of PD/PIs who applied to the IMAT program by extracting the list of Profile Person ID numbers from the applications list.

Patents. The evaluation team obtained patent data through the USPTO bulk downloads service available at https://www.google.com/googlebooks/uspto.html. Award numbers were extracted from the Federal

Support statement section of the patents and matched to IMAT project number from the IMPAC II database. The evaluation team explored gathering patent data through iEdison but found the USPTO records more complete.

Publications. The evaluation team obtained data from ExPORTER on publication information from publicly available Scientific Publication Information Retrieval and Evaluation System (SPIRES). SPIRES utilizes Thompson Reuters Web of Science and the Scopus databases. We downloaded publication files that referenced an IMAT award and extracted the grant numbers cited in the article as having supported the publication's research. These grant numbers were matched to IMAT project numbers.

Secondary Publications and Patents. In addition to compiling data on direct patent to grant and publication to grant citations (described above), the evaluation team also obtained citations of IMAT publications by patents. Citation data extractions from patents involved use of a fuzzy string algorithm to identify titles similar to published PubMed articles.

Archival data were downloaded using the assumptions in

Table 5. Appendix G contains the full archival data collection methodology.

Table 5. Archival Data Assumptions

Type of Archival Data	Assumptions and Notes
Patents and Patent Applications	Assumes that all inventors entered the grant number using one of four iterations in the Government Interest field. The patent application office maintains full text downloads from 2001 and onward; therefore, patent applications published prior to 2001 are not included in this analysis.
Publications	Assumes PD/PIs acknowledge IMAT grant numbers in the publication, as listed in PubMed. The number of project-related publications may therefore be much larger than the number retrieved by the evaluation team if PD/PIs neglected to cite an IMAT grant number where it would have been applicable. A small number of journals do not report grant numbers to PubMed. Results do not differentiate the type of journal article—all types are included. For example, reviews, journal articles, and letters will all be retrieved if they include the grant number.

Web-based Survey

The evaluation team developed a web-based survey to better understand the outcomes and overall impact of novel technology investments. The survey collected both quantitative and qualitative data. Each survey focused on the technology that was developed from the grant. The survey was administered using Qualtrics, a web-based survey platform, and pilot tested internally (with Ripple Effect staff) and externally (with volunteers) prior to launch. On average, the survey took 20 minutes to complete.

The survey was distributed to both IMAT and Comparison Group awardees. The survey pool originally consisted of 473 awardees for the Comparison Group and 705 for current and past IMAT awards. NCI's Program Officer developed a list of email addresses from grant applications and sent an initial email communication to this pool informing them of the survey. In order to reduce burden on PD/PIs who had more than one grant award, Ripple Effect contacted them and informed them that they could designate an alternate contact to complete one of the surveys on their behalf. Using the email list provided from NCI, a web link was sent to the survey pool from an NIH email address to encourage participation. Several reminder emails were sent to those who had yet to complete the survey. Participants were not offered any incentives to complete the survey.

A large number (n=237) of invalid email addresses from former and current awardees resulted after the initial contact email from NCI staff. The team searched for alternate email addresses based on the list of invalid emails and used this revised list to send out the survey. Over the course of launching the survey and sending reminder emails, the evaluation team encountered more invalid email addresses. Therefore, the response rates are presented in relation to the total number of valid email addresses (see Table 6).

Table 6. Web-based Survey Response Rates by Study Group

	Total Number Valid Email Addresses	Total Survey Respondents	Response Rate
Comparison	416	211	50.7%
IMAT	535	310	57.9%
Total	**951**	**521**	**54.8%**

A total of 521 survey responses, representing 310 IMAT awards, were collected. Eleven of the surveys marked "complete" were only partially complete. To be considered partially complete, respondents had to answer up to and including the question that asked for the trademarked or formally designated name of the technology or methodology (see Appendix H).

Because we wanted to estimate the difference between the IMAT and Comparison Groups with regard to various outcome measures, the evaluation team established the needed statistical power to detect differences a priori. Using G*Power software (version 3.1.9.2), the team inputted an alpha value of 0.05 for a two-tailed test to achieve power of 0.90. The sample size needed to detect a medium effect size of 0.5, and it was 210 across both groups (i.e., at least 105 in each group). Assuming a 40% response rate for the survey (n=394) and an alpha of 0.05 for a two-tailed test, 105 persons in each group would allow the detection of effect sizes as low as 0.33 with a power of 0.90. The response rate exceeded this minimum threshold.

The proportions of responsive and nonresponsive PD/PIs were consistent across fiscal years. R21/R33 awardees had slightly higher response rates than SBIR/STTR awardees for both the IMAT Group and the Comparison Group. The web-based survey data were complemented by qualitative data obtained from open-ended PD/PI interviews from a sub-set of successful IMAT applicants.

IMAT PD/PI Interviews

The evaluation team developed a telephone interview protocol to collect more detailed and nuanced information from successful IMAT awardees about their experience with the IMAT program and about the development path of their technology.

Sampling Plan. To determine the pool of interviewees, Ripple Effect drew a random sample of 100 IMAT awardees from FY2004 to FY2013. This 10-year span provided awardees across all mechanisms and thematic areas, while limiting the available pool of respondents to those familiar with the program's recent structure. The team drew the sample proportionally to the percent of awardees categorized by R21/R33 and SBIR/STTR, and oversampled by 20% to account for potential non-responses. The final sampling plan included 121 potential respondents. These PD/PIs were sent a link to schedule a phone interview during any work day. The evaluation team interviewed 82 PD/PIs during the data collection period, representing 82 distinct IMAT awards.

Interview Process. All interviewers received training and used a standardized, scripted introduction, and set of questions in order to minimize variation. Interviewers all held a PhD in a scientific discipline, and were assigned to interviews based on their availability. Interviewers took notes during the interview and with the interviewee's consent, recorded the interviews to confirm or clarify statements during the note cleanup process. The Evaluation Director participated in a subset of interviews for quality control monitoring and to ensure consistency across interviewers. The Evaluation Director also reviewed all interview notes and followed up with interviewers for more detail or background information where needed to facilitate future analysis. Recordings were deleted upon finalization of notes.

Code Development. Analysts thoroughly reviewed each question from a 20% sample (n=17/82) of PD/PI interview notes to generate initial codes. Code development involved both deductive and inductive approaches—the former focused on using existing hypotheses and theories to drive the analysis and the latter focused on drawing themes from the data. Codes evolved through an iterative process.

Coding Process. Analysts extracted quotes from each comment reflecting a single sentiment. Codes were then applied to each quote. Multiple codes could apply to quotes, and quotes were not always mutually exclusive. Because of this, the number of comments per topic area generally exceeded the number of interview participants. For the purposes of the PD/PI interview findings throughout the report, (n) refers to the number of quotes or comments related to the topic not the number of individual PD/PIs.

Coders had the flexibility to suggest, and manually enter, new code names into an open-text field when coding sentiments, ideas, and suggestions that did not fit within the existing coding scheme. This allowed additional codes and sub-codes to emerge using an inductive grounded theory approach. After all comments were coded to the appropriate topics, axial coding was conducted. Each code group was reviewed and analysts combined codes where appropriate, or disaggregated core themes that emerged within codes. Quotes from each code group were reviewed, analyzed, and summarized.

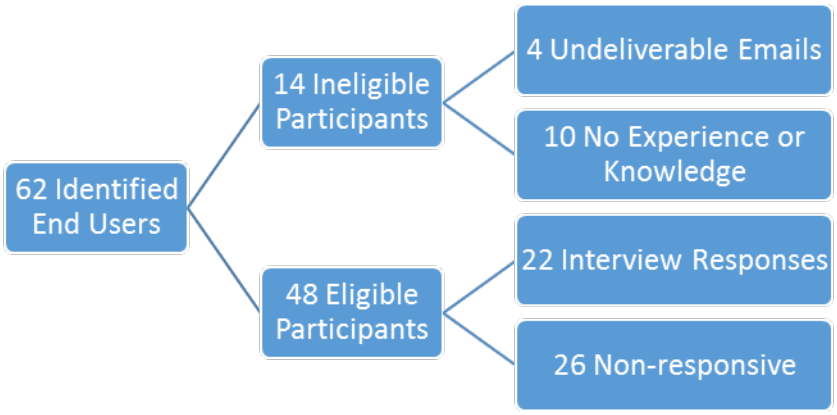
IMAT End User Interviews

IMAT technology End Users are clinicians, researchers, patients, or other individuals who used technologies developed with IMAT funding. The evaluation team developed a telephone interview protocol to collect information from End Users about their experiences using technology developed with IMAT funding. The process for identification of End Users is described in End User Selection Process. In total, 11 technology types were used to identify potential End Users and 62 End Users were contacted for an interview. End Users were sent a link to schedule a phone interview during any work day. The interview and data collection process was the same as the PD/PI process previously described.

Of the 62 initial End Users who were contacted, 10 stated that they had no experience with the technology and were excluded from further consideration. An additional four End Users' emails were undeliverable and were also excluded. Of the remaining 48 End Users, 22 from nine technology types responded to the interview requests, resulting in a 46% (n=22/48) response rate (**Error! Reference source not found.**).

The evaluation team interviewed 22 eligible End Users during the data collection period. The internal evaluation task lead participated in a subset of interviews for quality control monitoring and to ensure consistency across interviewers. The task lead also reviewed all interview notes and followed up with interviewers to provide more detail or background information where needed to facilitate future analysis.

Figure 8. End User Recruitment Process



End User contact information was more readily available for technologies that are more widely used, resulting in differences in the numbers of End Users contacted for each technology. Table 7 shows the number of End Users contacted and interviewed for each technology type.

Table 7. End User Interviewees by Technology Type

IMAT Award	Number of Eligible End Users Contacted	Number of End Users Interviewed
Cancer Detection Technology ***(R42CA108247-01 / FY2004)***	1	1
Development of an Automated Frozen Sample Aliquotter ***(R21CA114167-01 / FY2005)***	5	4
Technology for Sensitive and Reliable Mutational Profiling in Pancreatic Cancer ***(R21CA138280-01 / FY2009)***	11	2
Transfected cell arrays for cancer research ***(R21CA125285-01 / FY2007)***	2	1*
Surrogate and Sentinal Technologies to Monitor Stability of Cancer Phosphoprotein ***(R21CA125698-01A1 / FY2008)***	6	3
VEC3-Valve Enabled Cell Co-Culture Platforms for Cancer Biology Study ***(R21CA155572-01A1 / FY2011)***	2	1
Microfluidic 3D Assays for Metastatic Cancer ***(R33CA174550-01 / 2013)***	6	4

IMAT Award	Number of Eligible End Users Contacted	Number of End Users Interviewed
Microfluidic Channels for High Density, High Performance Culture Assays ***(R21CA122672 / FY2007)***	5	2
Application of Technologies for Interactome Network Analyses of Cancer Mutations ***(R33CA132073-01 / FY2008)***	3	2
Multiplexed Reiterative Immunofluorescence Analyses via Engineered DNA Circuitry ***(R21CA147912-01 / FY2010)***	3	3
Emerging Technologies Applied to the Discovery of Human Tumor Viruses ***(R33CA120726-01A1 / FY2007)***	5	0
Total	**49**	**23**

*Interview not included in analysis; participant did not have direct knowledge of the technology.

The evaluation team used a similar data analysis approach as described in the PD/PI interview analysis. However, due to the smaller sample size, analysts thoroughly reviewed each question from a 27% sample (n=6/22) of End User interview notes to generate the coding scheme. For the purposes of the End User interview findings throughout the report, (n) refers to the number of quotes or comments related to the topic not the number of individual PD/PIs.

Findings

The evaluation team began its analysis by gathering and examining archival data on grant applications and awards, publications, and patents, while waiting for OMB and IRB approvals for web-based survey and interview data collection.

Findings from the analyses are presented in line with the major logic model areas (Initial Investment, Program Activities, Program Outputs, and Outcomes).

Initial Investment

As illustrated in the logic model, there are a number of investments made into the IMAT program. NCI invests grant funding, including support for PD/PIs and research teams, as well as grants management support. The PD/PIs' institutions provide varying levels of support and infrastructure, and the PD/PIs themselves provide investments, such as via their previous research and high risk/high reward ideas. This section presents analysis of these investments and any notable patterns and trends. Greater detail about the IMAT program applications, awards, funding mechanisms, and thematic areas can be found in Appendix B.

Feedback on Grant Application Process

During the interview, PD/PIs were asked to provide feedback about the NIH IMAT application, submission, and review process. Overall, the majority of applicants found the process to be smooth and straightforward, with few challenges reported, as described below.

Application and Submission Process. Of the interview comments, the more than half of PD/PI comments suggested that the application process (n=49/93, 53%) and the submission process (n=71/96, 74%) were straightforward, clear, well thought-out, and well-suited to their goals and ideas. In particular, participants mentioned the usefulness of writing milestones, a hallmark of phased award programs, and said that the milestones helped structure the application for peer review. A few PD/PI comments (n=14/93, 15%) described the application and submission process as clear and neither easy nor hard; they also did not think the application and submission processes were like a typical grant-writing experience.

A few PD/PI comments (n=8/93, 9%) mentioned that the uniqueness of IMAT makes it a difficult but useful mechanism. PD/PIs mentioned several specific difficulties, such as trouble framing how the research applied to IMAT, transitioning from hypothesis-driven to technology-driven grantsmanship, and convincing reviewers that the research was worthy of funding. Even though PD/PIs mentioned these difficulties, they agreed that the process for applying was clear. Additionally, a few PD/PI comments (n=14/93, 17%) mentioned that the grant-writing process is challenging; reasons included those of general applicability (such as wanting to include too much information, and packaging the grant as something the reviewers will understand) to those specific to a unique features of IMAT such as difficulty writing milestones.

A few PD/PI comments (n=8/93, 9%) suggested for improvement in the application and submission process. Some suggested streamlining the application process to avoid repetition, and PD/PIs suggested clearer definitions for several terms, such as “technology” and “novel tool,” to ensure interpretation is accurate. In order to make the application process smoother, others suggested that NCI should provide tools for applicants, such as guidance on how to select the best technology category, opportunities to be coached to write a successful application, and access to past successful grants.

Review Process. The majority of PD/PI comments (n=62/100, 62%) described the review process as good or as expected. Some positive sentiments were as follows:

- IMAT’s review panel was better than other review panels because reviewers consider potential implications and are willing to take risks.
- The IMAT review panel was “excellent” and “high quality.”
- The IMAT panel seemed to have a range of expertise and were highly qualified to provide feedback.

Other PD/PIs had negative feedback about the review process (n=16/100, 16%). Some negative sentiments were as follows:

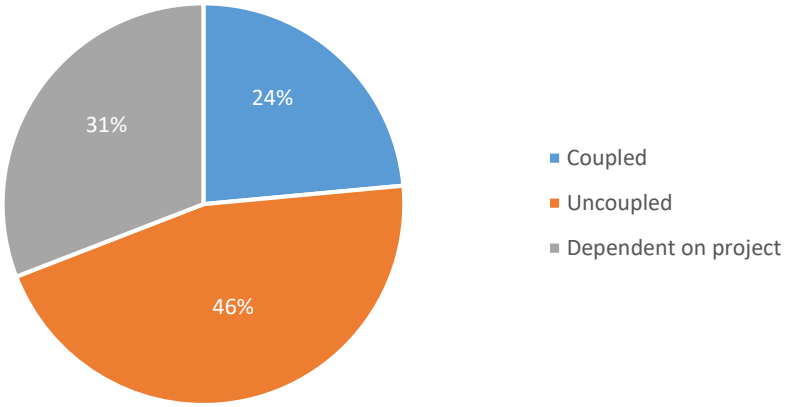
- Review panels did not have a good understanding of "high risk," "high impact," or "innovative" research or that the review process involved a certain level of luck.
- There was too much favoritism or there were politics involved in the review process.
- Panel members may have had difficulty stepping away from the hypothesis-driven view.

Alignment with Research Goals. Almost all PD/PI comments (n=73/75, 97%) generally described the IMAT program as a good or great fit to help them meet or achieve their research goals. In particular, several PD/PIs noted that IMAT is the only opportunity to engage in non-hypothesis-driven research, to engage in innovative research, and to explore new technologies, making the IMAT program a natural fit for their respective research projects. Several PD/PIs suggested that NIH would benefit from more funding dedicated to risky, innovative research. Additionally, others mentioned that IMAT program staff realize the potential for the IMAT-funded research to be expanded outside of cancer and biology research.

Two PD/PIs (n=2/75, 3%) noted that IMAT may not have been the best fit for their research goals. One PD/PI awarded an SBIR/STTR in 2004 felt a disconnect between being a small business and the perception that the IMAT program was very academically oriented. Another PD/PI was unsure about the weight of basic research mechanisms compared to clinical relevance and how research with more emphasis on research compared with clinical application fit in the larger program.

Coupled vs. Uncoupled. The PD/PIs were asked about the utility of coupled compared with uncoupled awards (Figure 9).

Figure 9. Coupled or Uncoupled Preferences



Some PD/PI comments supported the coupled mechanism (n=16/68, 24%). One PD/PI suggested that there should be a re-review process before awarding R33 funds. Some of the reported positive aspects of the coupled process were as follows:

- It supports continuation of the technology.
- It provides an opportunity to commercialize.
- It provides an incentive to continue developing the technology.
- It allows PD/PIs to write fewer grants.

Almost twice as many PD/PI comments (n=31/68, 46%) described a preference to the uncoupled approach to the coupled approach. PD/PIs who supported the uncoupled mechanism highlighted several advantages such as:

- It allows time to evaluate the technology after the R21 or for the technology to change.
- It allows the R21 to remain high risk.
- It is difficult to justify the R33 without R21 data.
- Different structures and needs are required for the two mechanisms.
- It forces the PD/PI to focus on the milestones of the R21, and the R21 is not always completed.

Some PD/PI comments (n=21/68, 31%) said that the coupling preference should depend on each project and listed advantages similar to the aforementioned for both approaches. PD/PIs suggested that the transition between the two grants should be expedited, and a program officer should guide the PD/PI throughout the transition.

Principal Investigators and the Research Team

The PD/PI named on the grant application was supported by a range of research team members. Based on the 310 grantees responding to the survey question about research team composition, IMAT supported over 1,550 research team members. Molecular biologists were the most common research team members, followed by engineers and chemists (Table 8).

Table 8. Survey Data on Research Team Composition

Answer	Max Value	Average Value
Molecular Biologists	8	1.0
Engineers	10	0.9
Chemists	9	0.9
Biologists	14	0.8
Clinicians	7	0.5
Biochemists	15	0.5
Other	6	0.3
Biophysicists	6	0.2
Physicists	6	0.1
Materials scientists	2	0.1

Previous Research

In the survey, awardees were asked if the technology or methodology developed under their IMAT grant had any relation to earlier technology/methodology that had been used by either themselves or someone else. They were also asked whether they had applied to other NIH programs for support, and whether they knew of other NIH programs that would have been a suitable fit for their NIH application. Similar questions were asked in the PD/PI interviews.

Survey respondents identified more than 250 pre-existing technologies that served as the basis for technology developed by IMAT. Additionally, almost half of the PD/PI interview comments (n=60/125, 48%) described that their research was related to earlier technology/methodology developed either by themselves or by someone else. Interviewed PD/PIs explicitly mentioned that ideas came from prior IMAT grants, other NIH grants, and awards from other agencies, including Centers for Disease Control and Prevention (CDC), American Cancer Society (ACS), and Defense Advanced Research Projects Agency (DARPA); or from collaborations with other scientists; or from their own post-doctoral research.

Twelve percent (n=22) of the IMAT survey respondents indicated there was no preceding technology or methodology for their idea compared to 22% of non-IMAT funded grantees. Complementary to the survey findings, PD/PI interview comments (n=57/125, 46%) noted that the ideas for the new technologies were completely novel and were generated based on need to help fill gaps or address limitations in the field. Participants described these ideas and the resultant technologies as completely novel or groundbreaking. These innovative ideas were conceptualized through conversations and brainstorming with colleagues, accidental observation, and experiments to satisfy curiosity. Some interview participants reported having made new discoveries or observations unlike anything that had then existed in the field of study.

Prior Grant Applications. As part of the survey, PD/PIs were asked about grants and grant programs for which they had applied. According to the survey data, most PD/PIs (72%) applied exclusively to the IMAT program. In considering other available programs, 63% reported that the IMAT program was the only one appropriate for their research, and 28% noted that at least one other NIH program may have been appropriate. A small percentage of awardees (9%) indicated that several other programs may have served as a suitable alternative.

Figure 10. Other Funding PD/PIs Would Have Pursued Without IMAT Funding

NIH Funds	General NCI Awards
	R21s
	SBIRs
Other Funds	Government Funding
	Pharmaceutical Companies
	Foundations
	Other Private Funds
	Institutional/Start-Up Funds

As a complement to the survey question, interviewed PD/PIs were asked for additional details regarding whether they would have applied for other funds had they not received IMAT funding. The PD/PIs responses were fairly evenly distributed, with about a quarter of comments (n=19/75, 25%) indicating that they would have applied for other NIH funds, and others (n=15/75, 20%) indicating that they would have applied for funding outside of NIH (Figure 10). Participants also indicated that they had applied for other NIH funds and were rejected or that they had received other NIH funds in addition to IMAT awards. A few PD/PIs indicated that they had received additional private funds beyond their IMAT awards.

Many PD/PIs (n=20/75, 27%) stated that they would have pursued other funds in the event they were not awarded IMAT funds, but that other funds would not have been as desirable as IMAT funding. PD/PIs cited various disadvantages to funding other than IMAT funding, including:

- Other funding would not have allowed the technology to develop as far/fast
- The PD/PI research would not have been as successful as with IMAT funding
- Other funding would have required a change in focus.
- The PD/PI would have had to have done additional work to apply.

In contrast, other PD/PIs (n=21/75, 28%) said they would not have pursued alternative funding mechanisms for the following reasons:

- They did not have enough preliminary data to apply.
- No other funding mechanisms would have been appropriate.
- Another mechanism would not have provided enough money.
- The research was too risky for any other mechanisms.
- They did not have the time/ability to pursue other funds.

Advantages of the Technologies

PD/PIs that were interviewed were asked to describe the primary advantages of their technology development. Many PD/PI comments (n=34/98, 35%) discussed advantages specific to their respective technologies. Other PD/PI comments (n=15/98, 15%) described advantages in more general terms, stating that the major advantage of their technologies was that these innovations addressed a gap in the science. The remaining PD/PI comments (n=49/98, 50%) mentioned other major advantages of technology, including increased efficiencies, such as ease of use, automation, time and cost savings, scalability; improved quality; improved precision; and improved accuracy.

Anticipated Outcomes

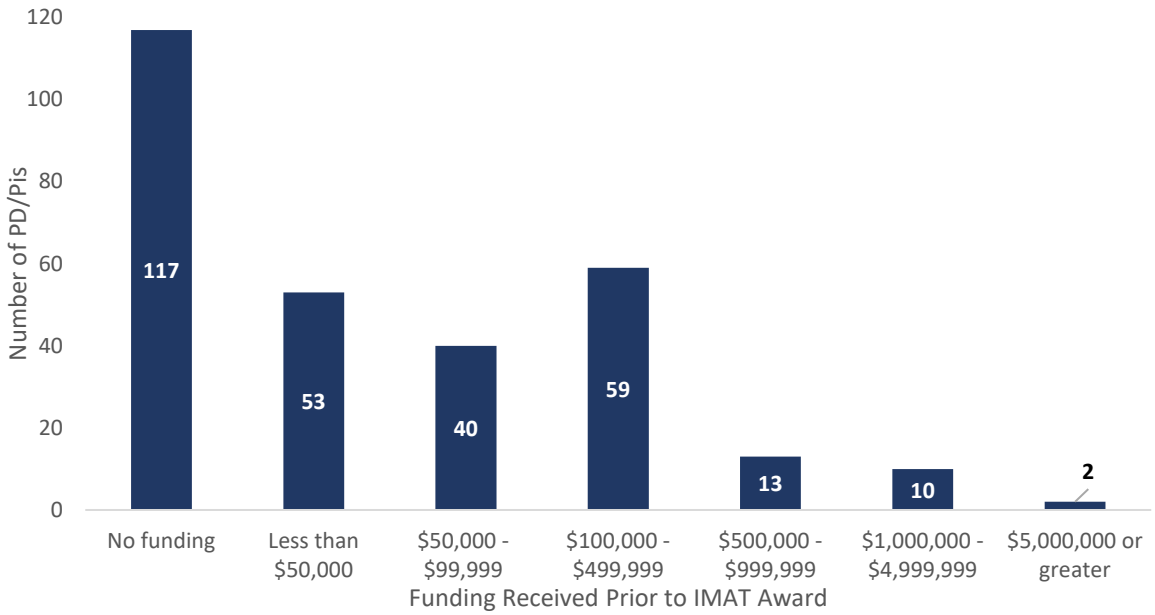
About a quarter of the PD/PI comments (n=23/91, 25%) discussed technical aspects of the technology and associated anticipated outcomes. The remaining comments described potential uses including research tools (n=20/93, 22%), diagnostic tools (n=17/93, 19%), drug test/targeting (n=9/91, 10%), use outside of cancer research (n= 6/91, 7%), commercialization (n=5/93, 5%), and other miscellaneous uses (n=11/93, 11%). Figure 11 describes ways in which PD/PIs thought their technologies would contribute to the field.

Figure 11. Anticipated Uses for IMAT Technology

Prior Funding

On the survey, awardees were asked to indicate the amount of funding obtained for their research idea and/or technology prior to the IMAT grant's award. Over 90% (n=269) reported receiving less than $500,000, and more than 40% (n=117) indicated they had received no funding. This distribution of funds highlights the importance IMAT funds played in starting innovative technology initiatives. The full distribution of funding categories is presented in Figure 12.

Figure 12. Funding Amounts Obtained Prior to IMAT Award



High Risk/High Reward Concepts

One key feature of the IMAT program is its investment in high risk/high reward projects. In the survey, IMAT grantees were asked to rate their projects on a 0 to 10 scale both for riskiness and for potential for reward. Figure 13 presents a heat map depiction of this ranking with clear clustering around high risk/high reward projects.

Figure 13. Matrix of Self-Reported Ratings of Risk and Reward Levels of Technology/Methodology

Potential Significance/Reward of Research →

Riskiness of Proposal ↓

	0	1	2	3	4	5	6	7	8	9	10	Total
0											1	**1**
1						1			1		1	**3**
2							1			2	1	**4**
3				1			1	5	3	4	1	**15**
4							4		2	3	2	**11**
5						2	2	4	8	11	11	**38**
6							1	5	16	11	5	**38**
7			1		1			13	18	22	15	**70**
8							2	6	24	20	10	**62**
9							1	4	6	17	5	**33**
10							1	2	3	5	18	**29**
Total	**0**	**0**	**1**	**1**	**1**	**3**	**13**	**40**	**81**	**95**	**70**	**304**

NIH Support and Interactions with NIH Program Officers and Grant Staff

The survey asked awardees about the utility of their interactions with NIH both before and during the grant award. More than half (n=182, 61%) had contact with NIH program representatives *before* submitting their application and of those, 73% found meetings or discussions productive and useful for developing their research/technology for their grant. Just 7% indicated the meetings or discussions were not productive, and 18% reported these early interactions were somewhat productive and useful.

A larger portion of awardees (n=232, 78%) reported interactions with NIH program officers and grant staff during the grant period than reported interactions before submitting their application. Most (69%) of these 232 awardees who had interactions with NIH staff during the grant period indicated that their interactions were productive and useful for developing their research/technology, while 20% thought interactions were somewhat productive and useful, and 11% reported that interactions were not useful or productive.

Although interviewed PD/PIs were not specifically asked about interaction with NCI staff, 14 PD/PIs (n=14/93, 15%) voluntarily commented that NCI staff were extremely helpful, encouraging, and responsive to questions. They felt that program staff were especially useful in helping to frame ideas to fit IMAT standards, generating ideas, and providing advice. PD/PIs who contacted program staff with questions were highly satisfied, and several PD/PIs specifically mentioned staff by name or title and that these staff were particularly responsive. As one participant stated:

> *"The IMAT program staff was helpful in speaking with me about the milestone portion of the grant and making sure they were framed with appropriate clarity. They also made sure the milestones – in terms of the evaluation – would be reasonable."*

PI Meetings. According to the survey, over 85% of IMAT awardees (n=257) reported attending the annual IMAT grant meeting. Of these awardees, approximately 53% reported that these meetings helped catalyze new projects with collaborators beyond key personnel. The remainder (47%) indicated "maybe." However, "no" was not a response option for this survey question therefore "maybe" responses likely include a range of sentiments (e.g., too early to report, collaborations did not lead to new projects, no collaborations).

As a complement to the survey findings, the interviewed PD/PIs were asked about the utility of the IMAT grant meeting. The PD/PI interview comments (n= 55/98, 56%) suggested that the annual IMAT grant meeting was generally well-received by the interviewed PD/PIs. In particular, PD/PIs enjoyed the opportunity to collaborate, learn, share new knowledge, and listen to speakers and presentations. PD/PIs noted that the meeting was well-managed or organized, that the small structure was a good format, or that the meeting helped move technology forward. Some PD/PI comments (n=43/98, 44%) suggested to enhance the meetings, and these suggestions are listed in Figure 14.

PD/PIs were overwhelmingly positive about the IMAT staff, describing them as helpful, responsive, and providing excellent guidance.

Figure 14. Suggestions to Enhance the PI Meeting

More Interaction

- Casual/Unstructured Time (e.g., Breaks, Provide Information About Attendees Prior to Meeting)
- Structured Time (e.g., Q&A Sessions, Networking Events)
- Interactions with Reviewers

Larger Variety of Talks

- Clinical and Biological Problems to Understand How to Apply Technologies
- Creation of Small Businesses
- Workshop-Based Learning
- PD/PI Presenations
- Presentations From Complementary Fields
- Obtaining Further Funding

Larger Variety of Attendees

- Senior Level PD/PIs
- IMAT Alumni
- Small Businesses
- End Users/Other Tech Developers
- IMAT Applicants

Meeting Follow-Up

- Success Stories
- Booklet of Information About PD/PIs' Research

Miscellaneous

- Reduce Poster Time
- Similar Event for Technology Tranfer Offices
- Alternate Locations to Ease Travel Burden

Dissemination. Communicating research results and technology advancement is imperative to increase awareness and maximize the impact of research. Interviewed PD/PIs offered several suggestions for how NCI could help increase awareness through dissemination, including facilitating connections with companies to help commercialize new technologies, and increasing publicity of the IMAT program. PD/PI comments (n=14/69, 20%) suggested creating networking opportunities for IMAT awardees to increase awareness of the IMAT program and its resultant technologies. PD/PIs provided several ways to encourage more networking including websites, focused meetings with IMAT grantees, meetings with PD/PIs outside of IMAT, access to additional data/samples, access to specialists who could help work on the grant aims, social media connections, and general efforts to disseminate knowledge of new technologies. Additionally, some PD/PI comments (n=27/69, 30%) described a limited knowledge of business development that inhibited them from producing or distributing the technology commercially. PD/PI comments (n=15/69, 22%) provided several suggestions as to how NCI could connect PD/PIs with programs and companies to achieve commercialization, such as helping with technology transfer, early education on commercialization, helping to start companies or connect with companies, and establishing linkages with SBIR/STTR. PD/PI comments (n= 10/69, 15%) expressed concern either that many other PD/PIs do not know that IMAT exists or that IMAT generally needs to publicize better. PD/PIs specifically suggested creating a website or journal to share IMAT successes. Finally, three PD/PI

comments (n=3/69, 4%) stated that it is not NCI's place to disseminate information related to IMAT-funded research and that this is solely the responsibility of the PD/PIs.

Knowledge Contributions, Collaborations, and Funding

Of the PD/PIs who responded to the survey, almost all (n=154, 97%) reported positive experiences that fell into three broad categories, which are further described below: knowledge contributions, collaborations, and funding. The most frequently noted interactions resulted in knowledge contributions (n=110; 70%), followed by opportunities for collaboration (n=46; 29%) and funding (n=18; 11%). Of the four PD/PIs (3%) who reported negative experiences in their interactions with NIH, two PD/PIs explained that NIH program staff lacked knowledge about the technology under development, one PD/PI was disappointed that an NIH-collaborator ceased communication after a relationship had been established, and a fourth PD/PI described interactions with the program officer as "hostile or unresponsive."

Knowledge Contributions (n=110). PD/PIs generally described their interactions with program officers as supportive, helpful, valuable, useful, and professional. Specifically, PD/PIs noted that program staff provided contextual knowledge about the relevant scientific area, other technologies, or general insights that helped guide or direct their project. For example, several PD/PIs who were awarded an R21 noted that discussions with program staff were crucial for helping them develop and fine-tune a successful application. In a few cases, PD/PIs attributed a smooth transition from the R21 to R33 to program staff. Phone conversations between PD/PI and IMAT program staff and interactions at the annual IMAT PI meetings were fruitful for PD/PIs during the grant period. Through these interactions, PD/PIs explored questions, brainstormed ideas, and gathered advice that helped them identify specific milestones, focus or broaden the scope of their research, and shape strategies for evolving their technology development (e.g., encouragement from program staff to ready the technology for clinical use, suggested directions for commercialization). In addition to the scientific knowledge contributions, PD/PIs also valued explanation and clarification about the non-traditional IMAT program structure.

> "*Meetings and discussions were vital for developing the overall structure of the grant, including the specific aims and milestones, especially since this program emphasizes risk/reward as opposed to narrow focused hypothesis-driven grants.*" (R33 awardee)

Collaborations (n=46). Among the survey findings, most frequently, PD/PIs described the value of the annual PI meetings for the opportunity to network, brainstorm, and meet potential collaborators. One PD/PI who is quoted below found the meeting helpful for understanding the broader context of technology development and the challenges of getting it to market, sentiments echoed by a handful of other PD/PIs.

> *"The IMAT grant meetings were critical to developing strategies and identifying funding mechanisms for clinical translation and commercialization." (R21 awardee)*

PIs also reported that collaborations fostered by NIH staff outside the scope of the annual PI meeting resulted in connecting their research to clinical settings or extending the application of their technology. R21 awardees account for three-quarters of the PD/PIs who valued collaboration.

These survey results were complemented by the PD/PI interviews, where many PD/PIs described how internal collaborators assisted with expertise in fields such as biology, cancer, bioinformatics, chemistry, non-cancer-related diseases, and biochemistry. PD/PIs described having up to six internal collaborators within their institution. However, many PD/PIs only discussed general collaboration rather than providing a specific number of collaborators. Twenty-two of 82 PD/PIs said they did not collaborate internally due to lack of need or lack of relevant in-house expertise.

Whether internal or external, PD/PIs overwhelmingly described collaborations as useful in terms of providing crucial expertise.

PD/PIs discussed the role of external collaborators in similar fashion to how they described internal collaborations. PD/PIs described how external collaborators assisted with expertise in areas such as fiber optics, cancer, bioengineering, chemistry, translation, pathology, sugar analysis, equipment, microfluidics, imaging, math, prenatal diagnosis, infectious disease, engineering, open reading frames, and cell interactions. If PD/PIs gave a number of external collaborators, the range was one to five, but most PD/PIs discussed general collaborations rather than providing a concrete number. Fifteen of 82 PD/PIs said they had no external collaborators.

Most PD/PI comments (n= 29/63, 46%) described their most useful collaborations with others as a way to engage the expertise of others in various fields, specialties, or skillsets. Guidance and advice was also discussed as a crucial collaborative factor among PD/PI comments (n=11/63, 17%). Additionally, some PD/PI comments (n=10/63, 16%) mentioned that they used collaborator's samples and supplies to help move the research forward, and some collaborators continued on with the research beyond the IMAT funding period. PD/PI comments (n=10/63, 16%) also described detailed collaborations that occurred specific to their technology type. However, a few PD/PI comments (n=3/63, 4%) reported encountering challenges with collaborations: ineffective collaborators and a relationship that was established too late in the research timeframe to be of assistance were two specific examples of these challenges. Table 9 provides a list of disciplines in which collaborators worked.

PD/PI comments (n=41/84, 49%) mentioned various ways of meeting collaborators, including through conferences, through previously existing relationships, through the IMAT PI meeting, or by introduction through a shared acquaintance/networking/proximity. Twenty-nine PD/PI comments (n=29/84, 35%) said the PD/PI sought out collaborators based on the potential collaborator's area of expertise. Conversely, PD/PI comments (n=14/84, 17%) said that prospective collaborators sought out PD/PIs through a variety of ways, including being approached by a company, by reading one of the PI's papers, knowledge of the PI's reputation, or being generally interested in the PI's work.

Table 9. Reported Disciplines of Collaborators

Discipline
Anatomists
Bioinformatics Experts
Biologists (various)
Biotechnologists
Botanists
Chemists (various)
Clinicians/Clinical Specialists
Computational Flow Dynamics Experts

Discipline
Computer Scientists
Engineers (various)
Environmental Scientists
Geneticists
Genomics Experts
Imaging Experts
Immunologists
Infectious Disease Experts
Material Scientists
Mathematicians/Statisticians
Microfluidics Experts
Neuroscientists
Oncologists
Optical Scientists
Pathologists
Pharmacologists
Physicists
Radiologists
Stem Cell Experts
Thermodynamics Experts
Zoologists

Funding (n=18). According to the survey, a small number of PD/PIs found their interactions with program staff resulted in application for another award, knowledge of alternate programs, or identification of an appropriate Request for Proposals (RFP). PD/PIs valued the time program staff spent assessing their work and the advice that followed for locating funding sources when the project no longer fit the IMAT program.

Comparison Group Interactions with Program Staff

The evaluation team also examined Comparison Group survey data to ascertain the patterns that emerged in terms of interactions with program staff. They found these interactions were valued for the same reasons described by IMAT grantees (e.g., knowledge contributions, opportunities for collaboration and determining funding sources), but noted three differences in the patterns of reporting. First, the Comparison Group grantees mentioned opportunities for collaboration less frequently than IMAT PD/PIs (10% compared with 29%, respectively). When Comparison Group grantees mentioned collaboration, it was in the context of specific and intentional efforts by program staff to foster collaboration. IMAT grantees noted those instances, but it was also common for IMAT grantees to point to the structure of the annual IMAT meeting as an important opportunity to identify and initiate collaborations.

A second difference involved funding sources. The Comparison Group more frequently noted that staff offered assistance with identifying funding mechanisms to further the research once the technology no longer fit the program (16% compared with 11% IMAT).

Third, while the overall percentage of Comparison Group grantees that mentioned knowledge contributions was similar to those of IMAT grantees (72% compared with 70% respectively), the Comparison Group PD/PIs more frequently mentioned assistance with the administrative aspects of the grant process. For example, about 10% of the Comparison Group PD/PIs mentioned interactions to discuss managing budgets, timelines, or reporting structures and requirements. IMAT grantees rarely reported administrative support as the reason their interactions with NIH program staff were useful. Both groups most frequently and consistently pointed to the value of their interactions with NIH program staff for providing scientific knowledge that helped shape their specific project and the overall direction of their technology development.

Program Activities

Advancing the Technology

Interview participants were asked to describe how the technology advanced throughout the course of the research period. Answers varied but included taking iterative approaches, going beyond the initial plan and staying on track with the research as proposed. Interview participants also described some challenges they faced as the research progressed.

The majority of participants (n=38/79, 46%) reported advances that were technical, or very specific to the technology. Some PD/PI comments (n= 16/79, 20%) described taking an iterative approach to help advance technology development and refine the outcomes of the research. PD/PI comments mentioned that early failures helped them modify the technology for improved results. Other PD/PIs approached the technology development from multiple angles until they could arrive at a successful model or optimum results.

Some IMAT PD/PIs (n=7/82, 8%) reported expanding the capabilities further than originally proposed. For example, some PD/PIs reported that they were able to make the technology more robust and more reliable than expected. One PD/PI mentioned that he/she modified the original, research-only plan and was able to implement the prototype developed during the IMAT grant period. Other participants (n=5/79, 6%) reported validation as an important step toward advancing the technology to help demonstrate consistent and accurate results, ensuring dependability of the technology.

Some PD/PIs (n=8/79, 10%) described achieving the aims by strictly adhering to the proposed plan and meeting milestones within set timeframes. PD/PIs reported that following the predetermined plan helped keep them on track. However, some PD/PI comments (n=5/79, 6%) described challenges as they moved forward with their research, such as time constraints, slow and laborious methods, and, due to funding restrictions, the inability to hire additional experts. Two PD/PIs reported that other research groups developed similar approaches before the IMAT funding was over, leaving their technology obsolete and unmarketable.

Institutional Support

Institutional support is critical in order to help researchers successfully advance their work. PD/PIs were asked about the level of institutional support they received. PD/PI comments (n=20/85, 24%) expressed general support from their institutions via a positive working environment. Also, they mentioned that working in close proximity to colleagues from diverse interdisciplinary backgrounds provided collaborative advantages that helped progress the research.

Many PD/PI comments (n=47/85, 55%) reported receiving strong institutional support via resources and supportive actions to complete the IMAT research. Resources most commonly reported included

additional funding, provision of critical equipment, appropriate infrastructure, and provision of personnel to assist with supplemental work. One PD/PI described how his institution paid for 100% of his salary, so he could focus solely on his research without having to worry about bills or other expenses. Another PD/PI stated that his institution, built a "nano-scale fabrication clean room" specifically for this project, making the execution of the grant possible. As one PI stated:

> *"My institution is very supportive of the technology and development efforts. The institution helped deliver researchers to help further goals. The institution also has strong connections with local clinical researchers through its alliance with the [sic]. Based on results, there have been many applications to translate in the field of cancer and beyond. The institution is placed in a good position to advertise, which leads to further translation and dissemination."*

Conversely, some PD/PI comments (n=8/85, 9%) reported problems or challenges that arose as a result of weak institutional support. Although there was no general theme, some PD/PIs reported that their institutions perceived their work to be unimportant. Others reported challenges in completing the work due to working under strict or conservative rules and regulations. Two PD/PIs described changes in the institution as a barrier to the efficiency of the research (e.g., one institution went bankrupt, delaying the PD/PI's work). While PD/PIs reported both positive and negative institutional support, a third group (n=10/85, 12%) neutrally described little or no additional support (e.g., funding, material resources) from the institution but did not describe particular hardships or challenges as a result.

Program Outputs

The initial investments described above are intended to support awardees in further developing their technologies or methodologies, increasing collaboration, disseminating findings from the research, and seeking funding to continue development beyond the grant. Common outputs of these activities include publications, patents, presentations, and licenses. Each of these outputs is discussed in detail below.

IMAT Publication Trends

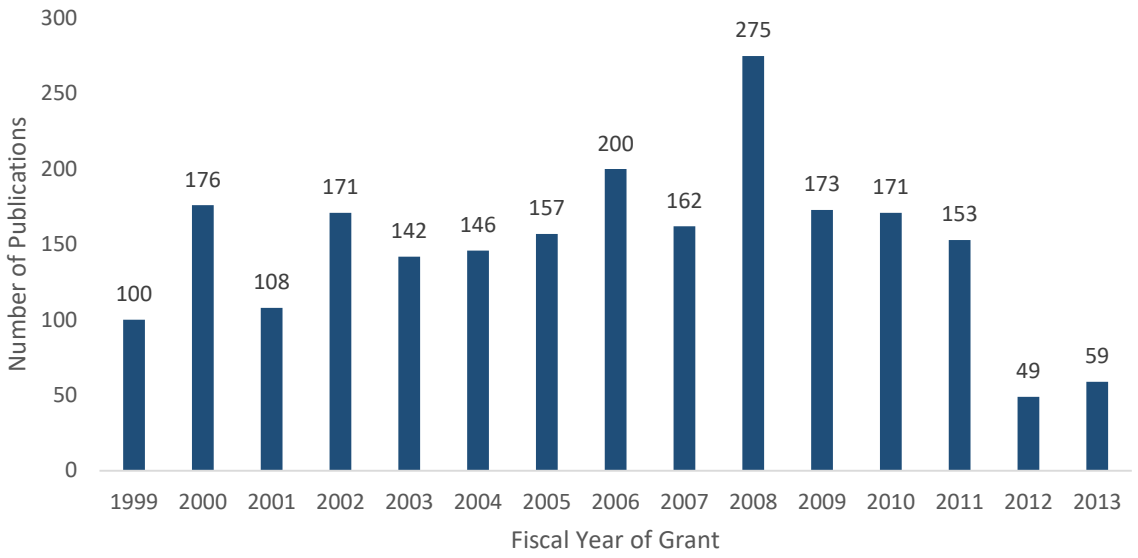
Of 705 IMAT awarded grants from FY1999 to FY2013, 63.4% (n=447) of PD/PIs produced publications. Multiple grant awards from different fiscal years can contribute to the development of a single publication. In this case, an individual publication was attributed to multiple grant years. As a result, the sum of all publications by grant award year was greater than the number of unique publications. A total of 2,054 unique manuscripts were published under grants awarded by IMAT between the years FY1999 and FY2013.

Time to Publication. The average number of years from initial grant award to a manuscript publication was three, with a maximum of 14 years. Among the Comparison Group, the average number of years from fiscal year of grant to manuscript publication was three with a maximum of 10.

Distribution of Publications. An average of 149.5 manuscripts were published each year, but the number of publications varied greatly by fiscal year, ranging from 49 in FY2012 to 275 in FY2008 (Figure 15).

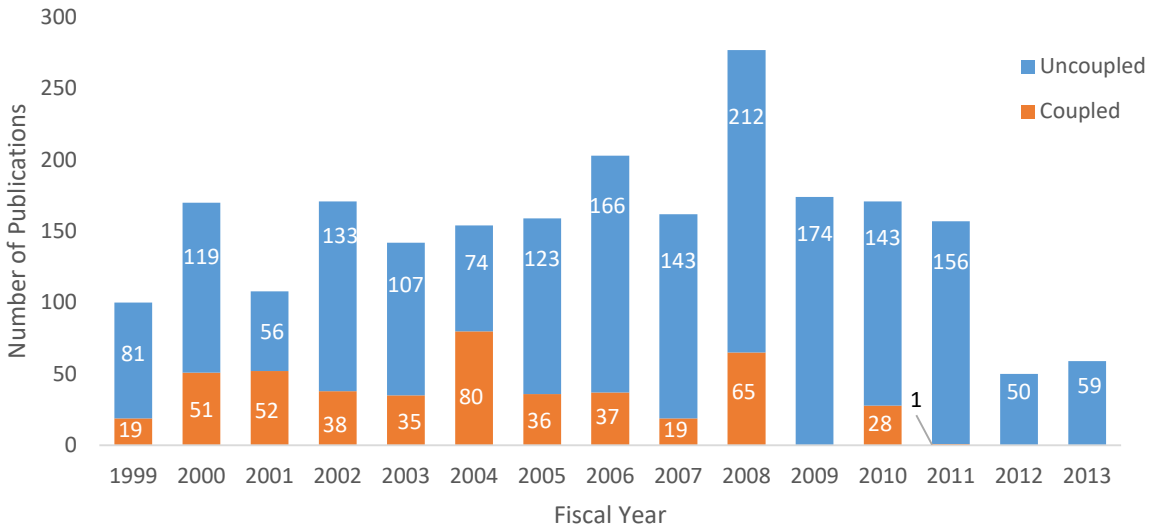
Overall, the mean number of publications per grant was 3.2. Of 540 grants under the R21/R33 funding mechanisms, 73.5% (n=397, mean=3.9) of the PD/PIs produced publications. Of 165 grants under the SBIR/STTR funding mechanisms, 23.6% (n=39, mean=0.97) of PD/PIs produced publications.

Figure 15. Total Publications by Grant Fiscal Year



The majority of IMAT-funded publications were produced by uncoupled grants (Figure 16).

Figure 16. Number of Publications Produced by Coupled and Uncoupled Grants



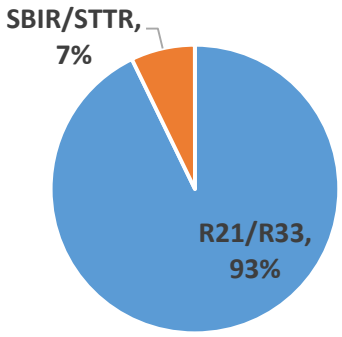
Distribution by Funding Mechanism and Program Theme. A total of 2,244 publications resulted from IMAT grants, of which 2,054 were unique. Between FY1999 and FY2013, the overall mean of publications per grant (including non-distinct publications) was 5.1 publications (Table 10). Grants funded under the R21 and R33 mechanisms produced significantly more publications (Mean=5.3) than grants funded under the SBIR/STTR mechanisms (Mean=3.3), $t(65)=2.60$, $p<.05$. The differences in the purposes of each type of funding mechanism may account for differences in publication generation. SBIR/STTR grants are reviewed differently and are focused on the commercialization of science (e.g., investors, commercialization, patents, follow-on funding). R21/R33 grants are focused on scientific advancement (e.g., used in other research work). Thus, PD/PIs with R21/R33 funded grants may focus more on producing publications than PD/PIs with SBIR/STTR funded grants which focus more on commercialization efforts.

Table 10. Total Non-Distinct Publications by Funding Mechanism

Funding Mechanism	Mean	Max	Total
Combined R21/R33	5.3	41	**2083**
R21	4.1	41	977
R33	7.1	36	1106
Combined SBIR/STTR	3.3	30	**161**
R41	6.7	13	20
R42	7	30	42
R43	1.9	10	40
R44	3.2	15	58
U43	1	1	1
Overall	**5.1**	**41**	**2244**

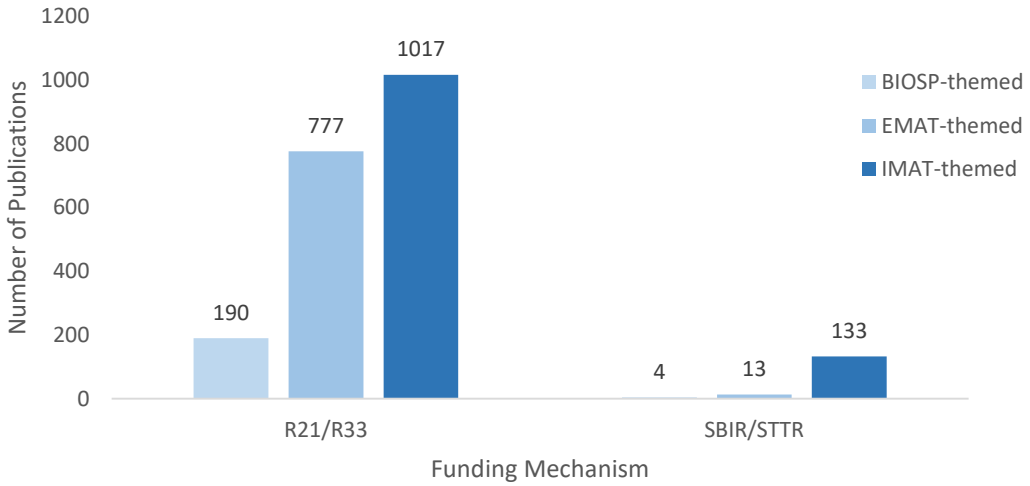
The R21/R33 funding mechanisms comprise 76.6% of funded IMAT grants, but they account for more than 90% of publications (Figure 17).

Figure 17. Percentage of Publications Produced by Funding Mechanism



The IMAT program provides funding under three thematic areas: IMAT-themed, EMAT-themed, and BIOSP-themed. IMAT-themed was the most common and BIOSP-themed was the least common thematic area under both categories of funding mechanisms. As shown in Figure 18, under the R21/R33 mechanisms, more publications were produced within the IMAT-themed area (n=1,017; 53.2%) than in either the EMAT-themed (n=777; 40.7%) or BIOSP-themed (n=190; 9.9%) areas.

Figure 18. Number of Publications by Theme and Funding Mechanism

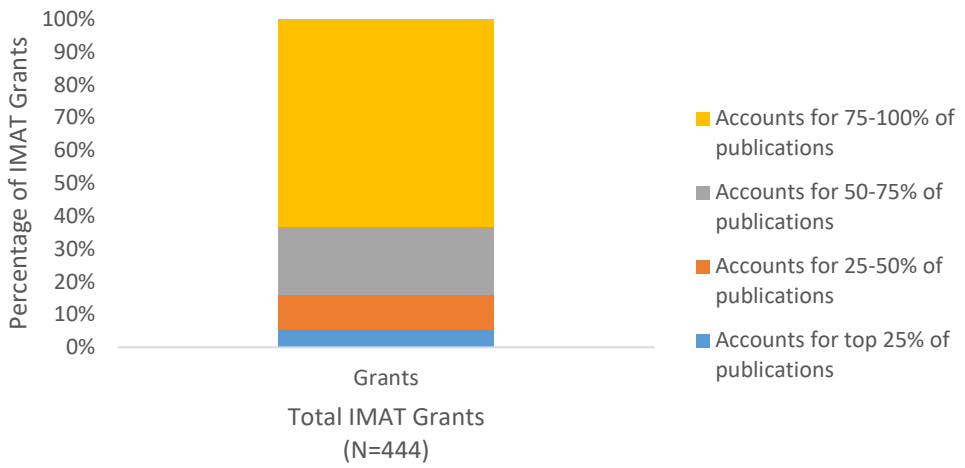


Under the SBIR/STTR mechanisms, more publications were produced within the IMAT-themed area (n=133; 89.9%) than in either the EMAT-themed (n=13; 8.8%) or BIOSP-themed (n=4; 2.7%) areas. It was expected that the BIOSP-themed area would have the fewest publications because this thematic area also had the fewest number of grant applications (n=427) and awards (n=52), compared with EMAT (applications n=1864; awards n=222) and IMAT (applications n=2,764; awards n=431) thematic areas.

IMAT grants were ranked by number of publications (including non-distinct publications) from the greatest to the least. The top 5, 16, and 37% of the grants made up approximately 25% (N=557), 50% (N=1,122), and 75% (N=1,684) of the total number of publications (Figure 19). The minimum number of

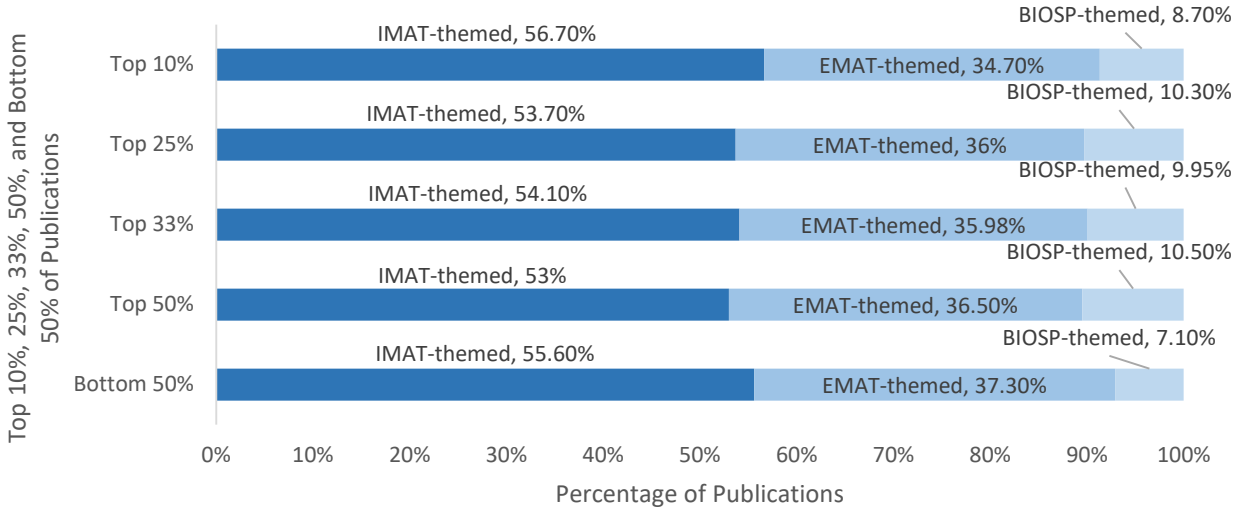
publications per grant was one while the maximum number of publications per grant was forty-one; the average number of publications per grant was five.

Figure 19. Percentage of Grants that Account for Publications (N=2,244) among IMAT Awardees by Quartile



IMAT grants were ranked by number of publications produced within thematic area. Within all quartiles, the IMAT thematic area of research consistently produced just over half of the publications (Figure 20). Of IMAT-funded research, 61.1% are within the IMAT-themed area, 31.5% within the EMAT-themed area, and 7.4% within the BIOSP-themed area; thus, the publication patterns are similar to the thematic area funding patterns.

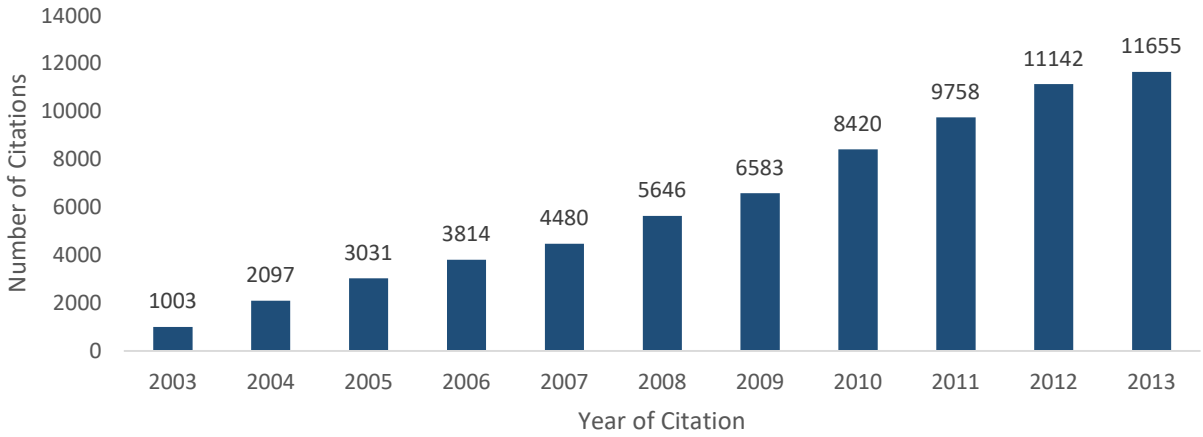
Figure 20. Percentage of Publications, Banded, by Thematic Code



Publication Citations. For IMAT grants, citations per publication ranged from 1 to 2,123 with a mean of 43.3. The mean number of citations to publications on research funded by R21/R33 funding mechanism was 47.0, and the mean number of citations to publications on research funded by the SBIR/STTR funding mechanism was 47.4. Figure 21 shows the number of citations by the year of the citation and demonstrates the increasing number of citations attributed to IMAT as the program progresses through

the years. Publication data were collected from Web of Science, which did not index this information prior to 2003.

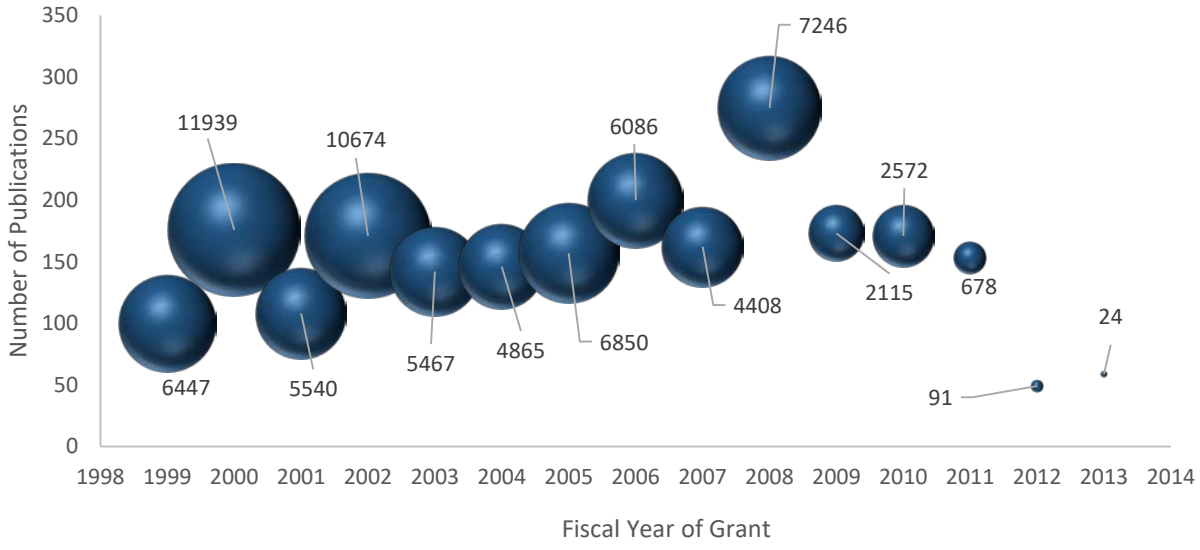
Figure 21. Number of Citations by Year of Citation



Note. Each data point represents the number of times an IMAT-funded publication from any publication year was cited by a manuscript during that year [Year of Citation].

Figure 22 displays the number of publications per fiscal year and the number of citations to IMAT-funded publications. The number of citations is represented by bubble size (data label). Even though the highest number of publications occurred for FY2008 grants, the biggest impact of the publications, measured by number of citations, was in FY2000 when only 176 publications were produced. The number of publications remained relatively steady between FY1999 and FY2011, but the number of citations varied greatly. The number of publications and citations declined in the last few fiscal years, likely due to the time lags between grant award, relevant publication, and citation.

Figure 22. Number of Citations per Fiscal Year by Number of Publications



Distribution by Journals, Institutions, and Principal Investigators. Publications describing IMAT-funded research were distributed across a wide range of scientific journals. The journals were ranked by number of publications attributed to IMAT funding, and the journals with the most publications are listed in Table 11. The most common journal was *Analytical Chemistry,* which published 5.3% of all IMAT-funded research, and the top 10 journals accounted for 23.8% of all IMAT-funded publications.[8]

[8] 4.7% of publications did not have an associated journal name. These publications were excluded this table.

Table 12 lists the 10 institutions with the highest number of publications. Appendix I lists all institutions and associated publications and patent awards and applications.

Table 11. Journals with the Highest Percentage of Publications

Journal Names	Number of Publications	Percent of Publications
1. *Analytical Chemistry*	104	5.3
2. *PloS One*	63	3.2
3. Proceedings of the National Academy of Sciences of the United States of America	52	2.7
4. *Journal of Proteome Research*	46	2.4
5. *Nucleic Acids Research*	41	2.1
6. *Cancer Research*	39	1.99
7. Nucleic Acids Research	33	1.7
8. *Lab on a Chip*	31	1.6
9. Molecular and Cellular Proteomics	29	1.5
10. Genome Research	27	1.4
Total	**465**	**23.8**

Note. Journal names were not provided by 97 publications; thus, the above calculations are based on a total of 1,957.

Table 12. IMAT-Funded Institutions with the Highest Number of Publications

Name of Institution	Number of Publications	Average Impact Factor	Number of Grants
1. University of Washington	112	8.7	10
2. Dana-Farber Cancer Institute	100	13.7	16
3. University of California, San Diego	78	7.9	12
4. University of California at Davis	62	4.7	7
5. University of Wisconsin-Madison	58	5.8	8
6. University of Texas – MD Anderson Cancer Center	56	6.8	5
7. Stanford University	52	9.6	10
8. George Mason University	48	10.8	5
9. University of Michigan	47	6.8	7
10. Johns Hopkins University	46	6.6	12
Total	**659**	**8.1**	**92**

Because of the different types of grant mechanisms, there were differences in scale between the R21/R33 and SBIR/STTR funding mechanisms (Table 13), and this difference reflects the goals of the funding mechanisms. Institutions in the top 10 within the R21/R33 mechanisms tended to be universities while the top 10 institutions under the SBIR/STTR tended to be businesses.

Table 13. Top Institutions with the Highest Number of Publications by Institution and Funding Mechanism

Institution (R21/R33)	Publications	Institution (SBIR/STTR)	Publications
1. University of Washington	112	1. Eno River Labs, LLC	30
2. Dana-Farber Cancer Institute	100	2. Calibrant Biosystems, Inc.	23
3. University of California, San Diego	78	3. Nanomedica, Inc.	13
4. University of California at Davis	62	4. Intrinsic Bioprobes, Inc.	10
5. University of Wisconsin-Madison	58	5. Cambridge Research and Instrumentation	7
6. University of Texas MD Anderson Cancer Center	56	6. Vitatex, Inc.	7
7. Stanford University	52	7. Anasazi Biomedical Research, Inc.	4
8. George Mason University	48	8. Newton Scientific, Inc.	4
9. University of Michigan	47	9. Twin Lights Bioscience, Inc.	4
10. Johns Hopkins University	46	10. Sci-Tec, Inc.	4
Total	**659**	**Total**	**106**

The 10 PD/PIs with the most publications across all funding mechanisms are listed in Table 14, along with the average impact factor of the publications and number of grants attributed to that PD/PI. Impact factors ranged from 4.0 to 12.41, and number of grants ranged from 1 to 6. The 10 PD/PIs with the most publications accounted for 19% (n=399) of all IMAT-funded publications.

Table 14. IMAT PD/PIs with the Highest Number of Publications

Principal Investigator (PD/PI)	Number of Publications	Average Impact Factor
1. Lam, Kit	58	4.70
2. Liotta, Lance	48	10.84
3. Beebe, David	47	5.60
4. Woods, Virgil	46	6.55
5. Vidal, Marc	42	12.41
6. Wang, Binghe	39	3.97
7. Shaughnessy, John	32	11.43
8. Tung, Ching-hsuan	30	4.69
9. Swenberg, James	30	4.32
10. Poole, Leslie	27	4.92
Total	**399**	**6.94**

The PD/PIs in the IMAT group have more publications and a higher average impact factor than those in the Comparison Group (Table 15 shows the relevant metrics for the top ten PD/PIs in the Comparison Group). A full list of PD/PIs with associated publications and patent awards and applications is provided in Appendix J – Principal Investigators with IMAT Awards.

Table 15. Comparison Group PD/PIs with the Highest Number of Publications

Principal Investigator (PD/PI)	Number of Publications	Average Impact Factor
1. Thompson, Paul	26	7.3
2. Devarajan, Prasad	24	4.1
3. Wu, Joseph	16	6.6
4. Varghese, Tomy	15	2.1
5. Rimm, David	12	8.5
6. Meltzer, Stephen	12	6.5
7. Smith, Richard	12	5.1
8. Fei, Baowei	11	4.5
9. Aebersold, Ruedi	10	5.3
10. Kung, Hank	9	4.1
Total	**147**	**5.4**

Publications ranged from 26 to 58 under the R21/R33 funding mechanisms and from 4 to 30 under the SBIR/STTR funding mechanisms (Table 16).

Table 16. IMAT PD/PIs with the Highest Number of Publications by Funding Mechanism

Principal Investigator R21/R33 Funding Mechanism	Number of Publications	Principal Investigator SBIR/STTR Funding Mechanism	Number of Publications
1. Lam, Kit	58	1. Swenberg, James	30
2. Liotta, Lance	48	2. Balgley, Brian	26
3. Beebe, David	47	3. Guthold, Martin	13
4. Woods, Virgil	46	4. Nedelkov, Dobrin	10
5. Vidal, Marc	42	5. Chen, Wen-tien	8
6. Wang, Binghe	39	6. Levenson, Richard	7
7. Shaughnessy, John	32	7. Duffy, David	4
8. Tung, Ching-hsuan	30	8. Gao, Jun	4
9. Poole, Leslie	27	9. Mach, Robert	4
10. Moore, Patrick	26	10. Rush, John	4
Total	**395**	**Total**	**110**

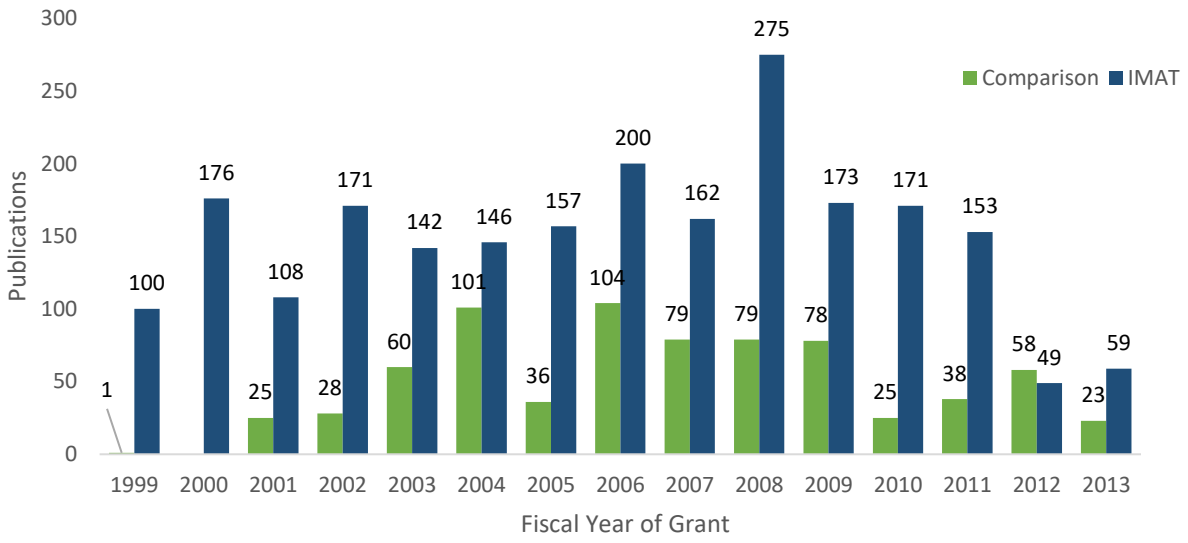
Regardless of funding mechanism, PD/PIs in the IMAT group have more than twice as many publications compared to the Comparison Group (Table 17).

Table 17. Comparison Group PD/PIs with the Highest Number of Publications by Funding Mechanism

PD/PI (R21/R33)	Number of Publications	PD/PI (SBIR/STTR)	Number of Publications
1. Thompson, Paul	26	1. Herweijer, Hans	6
2. Devarajan, Prasad	24	2. Higgins, William	6
3. Wu, Joseph	16	3. Roy, Hemant	6
4. Varghese, Tomy	15	4. Flynn, Edward	5
5. Meltzer, Stephen	12	5. Grimm, Elizabeth	5
6. Rimm, David	12	6. Mathis, J. Michael	4
7. Smith, Richard	12	7. Mousa, Shaker	3
8. Fei, Baowei	11	8. Jacquez, Geoffrey	3
9. Aebersold, Ruedi	10	9. Wakatsuki, Tetsuro	3
10. Kung, Hank	9	10. Wittwer, Carl	3
Total	**147**	**Total**	**44**

Publication Distribution Within the Comparison Group. Compared with the 2,054 unique publications attributed to 705 IMAT-funded grants, 733 unique manuscripts were attributed to 473 Comparison Group-funded grants over the same time period (Figure 23). Of 473 comparison grants, 50.3% (n=238) produced publications, which is less than the 63.4% IMAT-funded research grants that produced publications noted earlier.

Figure 23. Publications by Fiscal Year of Grant



There were differences in publication outputs by funding mechanism, when compared to the appropriate Comparison Group funding mechanisms (Table 18). Under the R21/R33 funding mechanism, IMAT-funded grants were attributed to significantly more publications than Comparison Group-funded grants, t(582)=-5.3, p<.05. However, under the SBIR/STTR funding mechanisms, there was no difference in the number of publications attributed to IMAT-funded grants compared to Comparison Group-funded grants. Additionally, IMAT R21/33 funded research compared to Comparison Group R21/R33 funded research generated significantly higher impact factors, t(398)=-3.9, *p*<.05, and the same pattern was detected examining IMAT SBIR/STTR funded grants compared to Comparison Group SBIR/STTR funded grants, t(72)=-1.7, *p*<.05. IMAT R21/R33 funded research compared to Comparison Group R21/R33 funded research generated a significantly higher average citation rate, t(490)=-5.0, p<.05, but there was no difference between IMAT and Comparison Group research regarding SBIR/STTR funding mechanisms.

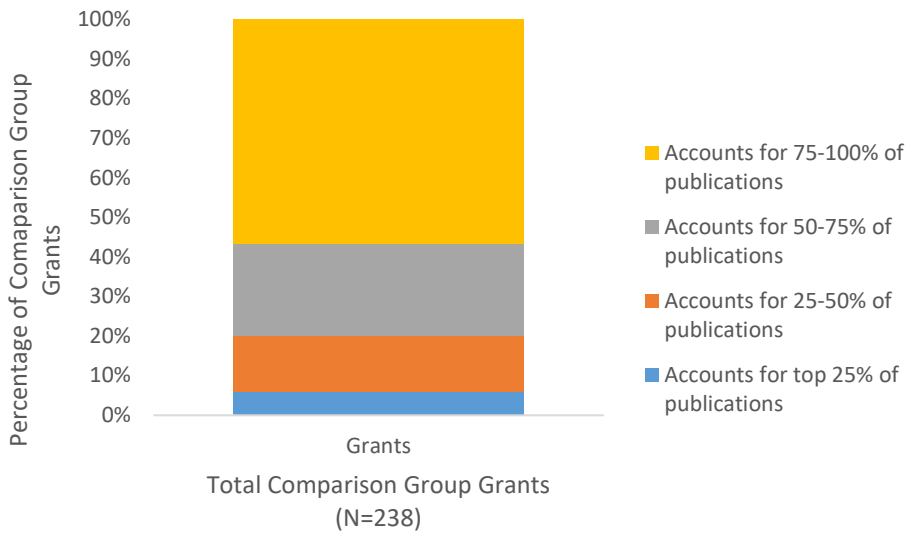
Table 18. Distinct Publications Produced by IMAT (N=705) and Comparison Group (N=473)

	Distinct Publications	Publications per Grant (Mean)	Impact Factor (Mean)	Citations per Publication (Mean)
IMAT R21/R33	**1910**	5.3	7.0	44.4
IMAT SBIR/STTR	**148**	3.3	4.9	43.7
Comparison R21/R33	**656**	3.3	5.3	30.1
Comparison SBIR/STTR	**77**	2.2	4.2	30.4

Grants were ranked by number of publications (including non-distinct publications) from greatest to least for the Comparison Group. The top 6, 20, and 43% of the grants correspond to approximately 25% (N=180), 50% (N=369), and 75% (N=553) of the total publications in the Comparison Group (Figure 24). The minimum number of publications was one per grant while the maximum number of publications was 26 per grant; the average number of publications for the Comparison Group was 3 per grant. The

Comparison Group published fewer publications overall compared to the IMAT awardees, although the difference in the sample size of total grants for the two groups differ by almost two-fold. In both groups, fewer than 10% of the grants accounted for 25% of the publications, while 20% or fewer of the grants accounted for more than half of the total publications.

Figure 24. Percentage of Grants that Account for Publications (N=736) Among Comparison Group by Percentiles



Cost of Research. IMAT awarded $422,531,335 in 705 grants from FY1999 to FY2013, and 534.2 publications were produced per $100,000,000 awarded. The Comparison Group awarded $242,382,652 in 473 grants over the same time period, and 303.7 publications were produced per $100,000,000.

IMAT Patent Considerations and Limitations

This evaluation examines patent applications by award for the technologies developed using IMAT program support. Patents are recognized as a reliable metric for assessing novel innovations linked to research and development investment (Kalutkiewicz & Ehman, 2014). Grueber & Tripp (2015) explain that the use of patents as an evaluation metric "greatly simplifies assessment of NIH investments by using patents as proxies for translatable innovation." Furthermore, because patents cite previous patents and the scientific literature, they serve as an indicator of how knowledge is linked and transferred among researchers and of the quality and value of the underlying research (Hall, Jaffe, & Trajtenberg, 2001). Specifically, biotechnology patents have been shown to have a more widespread impact ("high generality") and to cite previous patents in a wider range of fields ("high originality") than other drug- and medical-related patents (Hall, Jaffe, & Trajtenberg, 2001).

There are various indicators of patent quality. As an indicator of quality, Rothwell, Lobo, Strumsky, & Muro (2013) have found that patents obtained for research funded by the Federal Government tends to be "of especially high quality," and in fact are of higher quality than industry-funded patents. A study by Harhoff, Narin, Scherer, & Vopel (1997) found that the value of patents increases when they are renewed to the limit of their legally mandated expiration date. Not only are such patents cited more frequently in the literature than patents that are not renewed, but they also provide greater economic value to their rights-holders.

While successful commercialization often involves securing intellectual property rights through patents, it is important to note that not all IMAT research will lead to results that require patenting, independent of its commercial viability. The lack of a patent, therefore, should not be taken to indicate a lack of successful outcome for the IMAT-sponsored research (Kalutkiewicz & Ehman, 2014).

Another important consideration is the duration of the patent application and review process. In many cases, the length of time required to apply for and receive a patent may exceed the period of IMAT grant funding. Because of this extended length of time, this evaluation also considers patent applications.

In our data, patent applications and patent awards are distinct categories without overlap, meaning that some grants are reported to have patent awards without patent applications (these are patent applications that were converted to patent awards) and some grants are reported to have patent applications without awards (these are patent applications that were not converted to patent awards at the time of the data pull). This data structure occurs because of USPTO record-keeping conventions; at the time a patent application becomes a patent award, it is no longer searchable as a patent application.

All of the factors listed above must be considered when using patents as a method of evaluating the outcomes of IMAT grants.

Patent Applications and Awards. Of 705 IMAT awarded grants, 154 (21.8%) produced a patent application or award, resulting in 361 distinct patent applications and awards. The mean number of distinct patent applications and awards per any IMAT grant was 0.5 (361/705); and the mean number of distinct patent applications and awards per relevant IMAT grant (those grants that produced a patent application or award) was 2.3 (361/154).

Of 540 grants under the R21/R33 funding mechanisms, 23.3% (n=126, mean=0.7) produced non-distinct patents. Out of 165 grants under the SBIR/STTR funding mechanisms, 17.0% (n=28, mean=0.6) produced non-distinct patents.

Table 19 Patent Applications and Awards by Mechanism

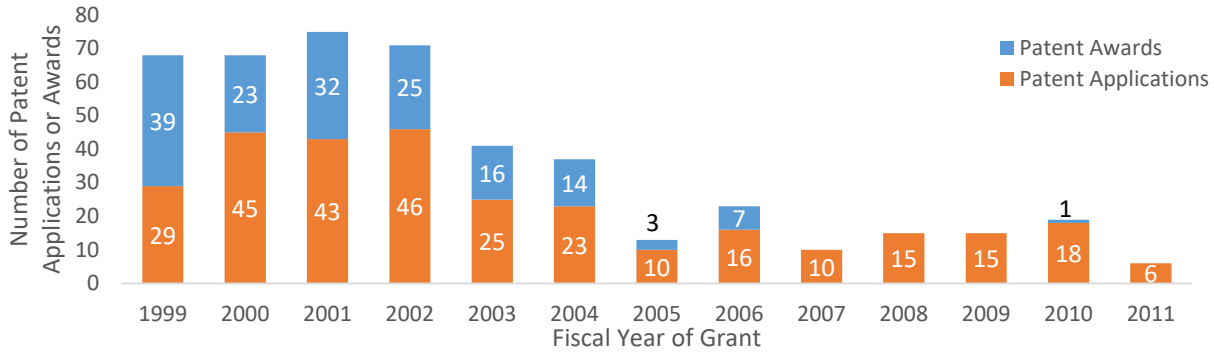
	Number of Grants	Grants with Patent Applications or Awards	Patent Applications and Awards	Non-distinct Patent Applications and Awards per Relevant Grants (Mean)
IMAT (all)	705	154 (22%)	461 non-distinct (N=361 distinct)	3.0
R21/R33	540	126 (23%)	360 non-distinct	2.9
SBIR/STTR	165	28 (17%)	101 non-distinct	3.6

The number of patent applications and awards[9] generally decreased over time (Figure 25); this finding is supported by the expected lag time between grant award and patent application or award. The average time between the fiscal year of the grant application and publication of patent award was 6.3 years,

[9] Note multiple grant awards from different fiscal years can contribute to the development of a single patent application or award, leading to individual patents attributed to multiple grant award fiscal years. As a result, the sum of all patents and applications by grant award year will be greater than the number of distinct patent applications and awards.

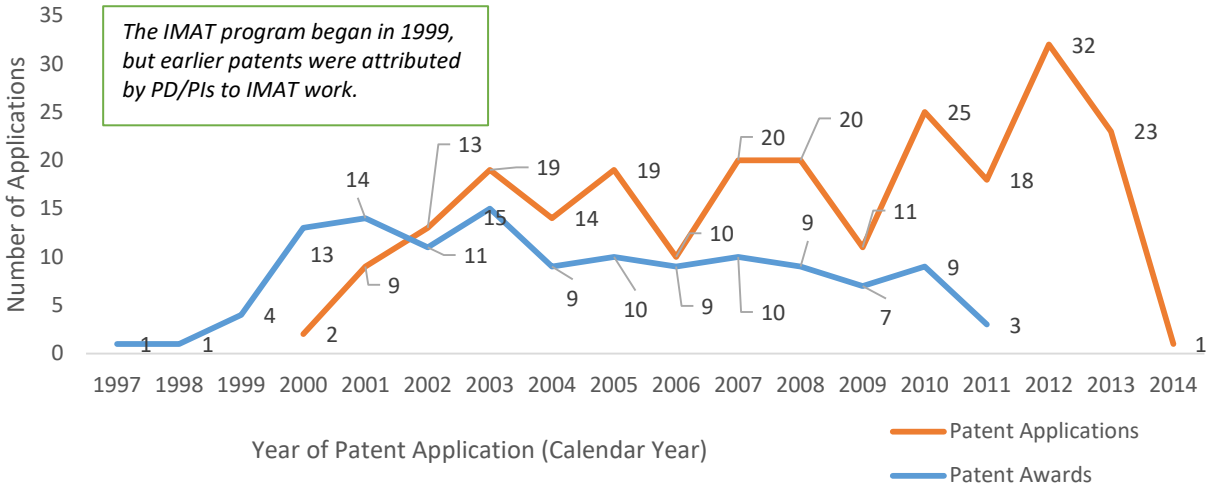
(std. dev. 3.0 years). The shortest time was 0.6 years, and the longest was 15.0 years. In support of the lag time, there were no patent awards or applications reported for FY2012 or FY2013.

Figure 25. Patent Applications and Awards by Year of Grant Application



We examined IMAT patent applications and awards by patent application year and found an overall upward trend (Figure 26).

Figure 26. Patent Applications and Awards by Year of Grant Application



Funding Mechanism and Program Theme. Since the focus of the SBIR/STTR funding mechanisms is commercialization, we expected that SBIR/STTR grants would produce a larger percentage of patent applications and awards compared to the R21/R33 grants. Although SBIR/STTR funded grants accounted for only 18.2% (28/154) of the funded grants that produced patents, they accounted for approximately one-quarter (n=84; 23.3%) of the distinct patents produced. Additionally, the mean number of non-distinct patent awards by the application and award producing SBIR/STTR funded grants was higher than the application and award producing R21/R33 funded grants (3.6 vs. 2.9; Table 18). The maximum number of non-distinct patent awards produced in the SBIR/STTR group was 20 compared with the maximum number produced in the R21/R33 group, which was 11.

Table 20 presents descriptive statistics on the non-distinct patent data for the R21/R33 and SBIR/STTR mechanisms. Because multiple awards may be associated with one patent application or award, the

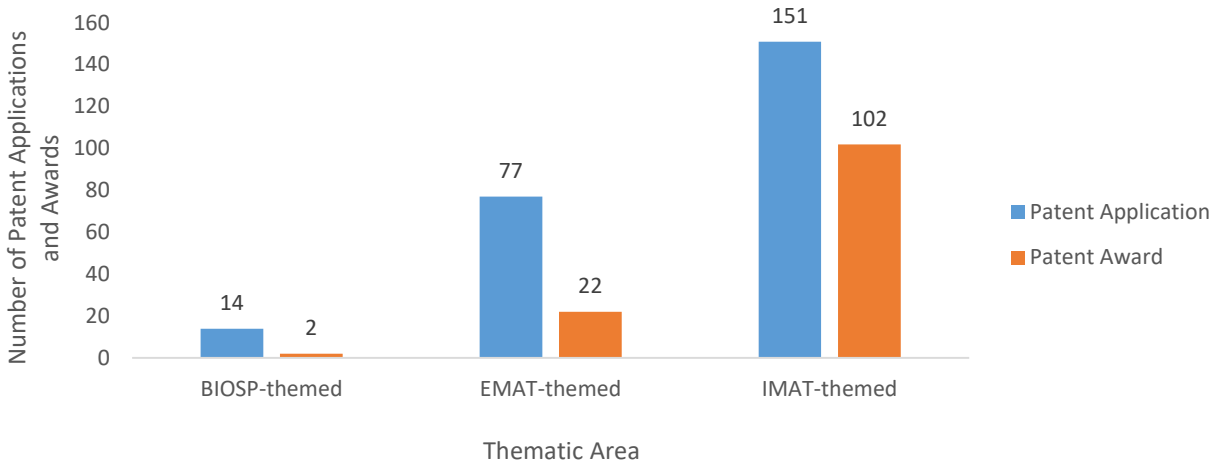
total number of non-distinct applications and awards sum to more than the total number of distinct patent applications and award (N=361; shown in Table 18). Note that all patent awards originated as patent applications; however, the USPTO status is available as a binary choice between patent application and patent award (the record is no longer searchable as a patent application once it becomes a patent award).

Table 20. Non-Distinct IMAT Patent Applications and Awards by Funding Mechanism

	Total Patent Apps and Awards (Non-Distinct)	Total Patent Applications	Mean Patent Apps per Grant	Max Patent Apps per Grant	Total Patent Awards	Mean Patent Awards per Grant	Max Patent Awards per Grant
Combined R21/R33	**360**	**248**	**2.2**	**16**	**112**	**1.9**	**11**
R21	167	123	1.8	6	44	1.8	8
R33	193	125	2.7	16	68	2.3	11
Combined SBIR/STTR	**101**	**53**	**2.1**	**7**	**48**	**3.7**	**20**
R41	2	2	2	2	0	--	--
R42	2	1	1	1	1	1	1
R43	45	27	2.3	7	18	2.3	4
R44	52	23	2.1	7	29	7.3	20
Total	**461**	**301**	**2.2**	**16**	**160**	**2.3**	**20**

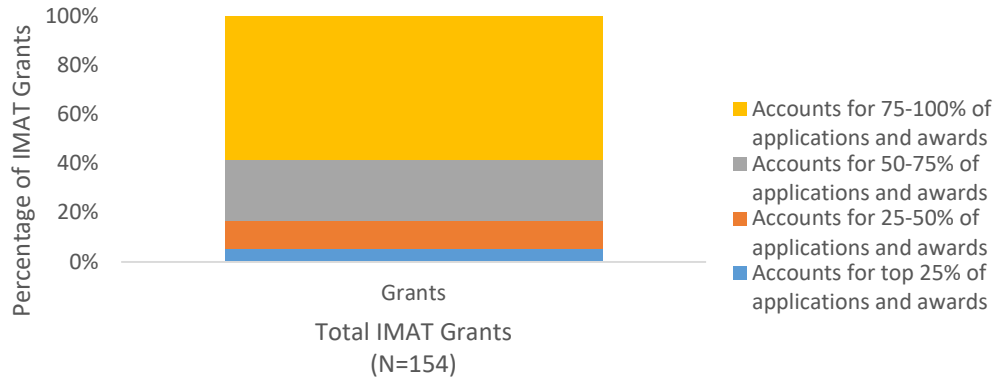
The IMAT-themed area produced the highest number of patent applications and awards compared with the BIOSP- and EMAT-themed areas (Figure 27). The IMAT-themed area accounted for 63% (n= 97) of IMAT grants but 70.1% (n=253) of patent applications and awards. In comparison, The EMAT thematic area accounted for 30.5% (n=47) of IMAT grants and a comparable 27.4% (n=99) of patents. The BIOSP-themed area accounted for 6.5% (n=10) of IMAT grants and 4.4% (n=16) of patents.

Figure 27. Number of Patent Applications and Awards by Thematic Area



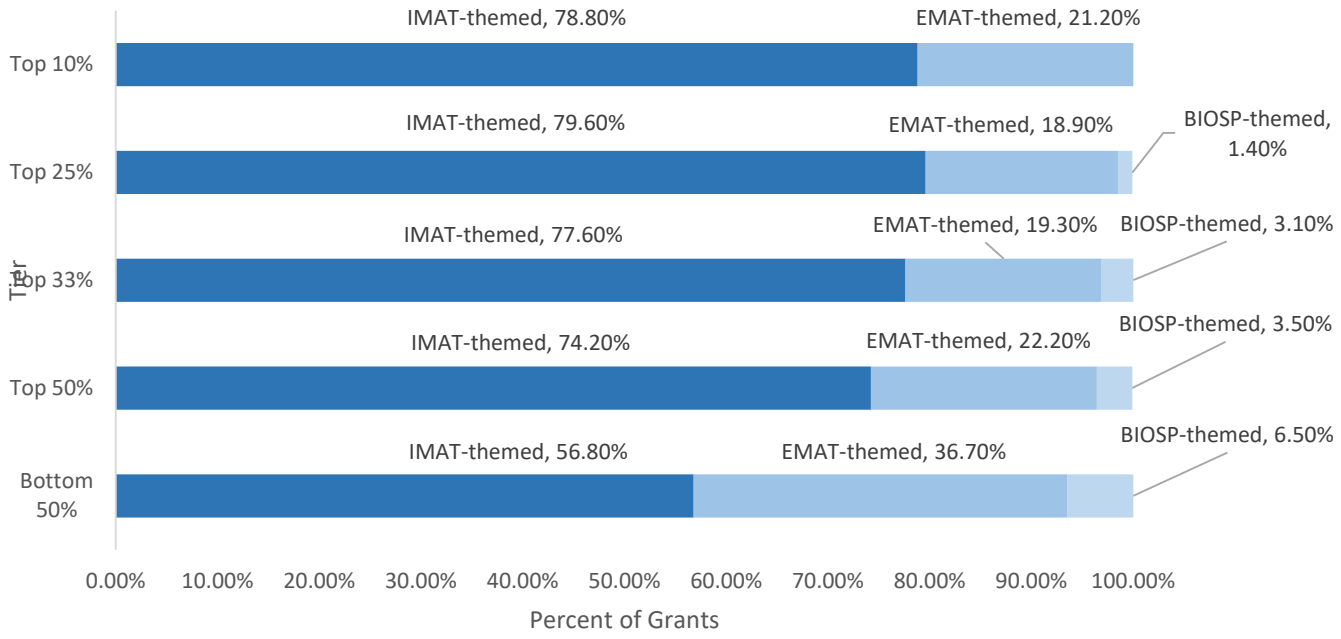
The IMAT grants were ranked by the number of patent applications and awards from greatest to least. There were a total of 461 patent applications and awards that were non-distinct from 154 grants. The top 5, 17, and 42% of the grants corresponded to approximately 25% (N=118), 50% (N=232), and 75% (N=346) of the total patent applications and awards (Figure 28). The average number of applications and awards were 3 per grant; the minimum number of patent applications and awards was 1 per grant and the maximum number was 27 per grant. More than 90% of the grants had fewer than 7 total patent applications and awards.

Figure 28. Grants Accounting for Patent Applications and Awards (N=461) among IMAT Awardees by Quartile



IMAT grants were ranked by number of patent applications and awards within each of the three thematic areas (Figure 28). Of the top 10th, 25th, 33rd, and 50th percentile, approximately three-quarters of patent applications and awards were produced within the IMAT-themed area, and this distribution closely reflects the distribution of grants among the three thematic areas.

Figure 29. Percent of Patent Activity Represented in the Top Percentages by Thematic Area



Patent Activity by Institutions and Principal Investigator. The ten institutions with the highest number of patent applications accounted for 35.6 (n=84) of all patent applications, and the ten institutions in number of patent awards accounted for 56.8% (n=71) of all patent awards (Table 21.

Table 21. Top Patent Applications and Awards by Institution

Institution Nam	Applications	Institution Name	Awards
1. University of Arkansas for Medical Sciences	16	1. Plasma Proteome Institute	20
2. University of Wisconsin, Madison	11	2. University of Arkansas for Medical Sciences	11
3. Johns Hopkins University	11	3. Institute for Systems Biology	9
4. Institute for Systems Biology	10	4. Harvard University	8
5. University of California at Davis	7	5. Prognosys Biosciences, Inc.	5
6. Prognosys Biosciences, Inc.	7	6. Saint Louis University	4
7. Harvard Medical School	6	7. Sanger Institute	4
8. University of California, Berkeley	6	8. University of California at Davis	4
9. Saint Louis University	5	9. IC Biosystems	3
10. Tufts University Boston	5	10. Third Wave Technologies	3
Total	**84**	**Total**	**71**

In contrast to the publication results, the number of patent application and awards did not differ in scale between the various funding mechanisms (Table 22). The 10 institutions funded by R21/R33 and SBIR/STTR, respectively, that had the most patent awards and applications produced 44.8% (n=124) of the total, and 81.1% (n=69) of the total patent applications and awards, respectively.

Table 22. Top Institutions for Patent Activity by Funding Mechanism

Institution (R21/R33)	Apps and Awards	Institution (SBIR/STTR)	Apps and Awards
1. University of Arkansas for Medical Sciences	27	1. Plasma Proteome Institute	20
2. Institute for Systems Biology	15	2. Prognosys Biosciences, Inc.	12
3. Harvard University	13	3. Third Wave Technologies	8
4. Johns Hopkins University	13	4. Medical Discovery Partners, Inc.	6
5. University of California at Davis	11	5. Intrinsic Bioprobes, Inc.	5
6. University of Wisconsin, Madison	11	6. Micronics, Inc.	5
7. Saint Louis University	10	7. Althea Technologies, Inc.	4
8. Harvard Medical School	8	8. IC Biosystems, Inc.	4
9. Massachusetts Institute of Technology	8	9. Bioproximity, LLC.	3
10. University of California, Berkeley	8	10. Mirna Therapeutics, Inc.	2
Total	**124**	**Total**	**69**

Table 23 lists the top investigators by both number of patent applications and awards and the top investigators by number of patent awards. The top ten PD/PIs in number of patent applications account for 31.8% (n=75) of all patent applications, and the top ten PD/PIs in number of patent awards account for 56.8% (n=71) of all patent awards.

Table 23. Top Principal Investigators by Number of Patent Applications

PD/PI Name	Applications	PD/PI ame	Awards
1. Shaughnessy, John	16	1. Anderson, N	20
2. Aebersold, Ruedi	10	2. Shaughnessy, John	11
3. Beebe, David	8	3. Aebersold, Ruedi	8
4. Chee, Mark	7	4. Lieber, Charles	8
5. Lam, Kit	7	5. Chee, Mark	5
6. Majumdar, Arunava	6	6. Bradley, Allan	4
7. Wang, Tza-huei	6	7. Heyduk, Tomasz	4
8. Engelward, Bevin	5	8. Lam, Kit	4
9. Heyduk, Tomasz	5	9. Neri, Bruce	4
10. Jay, Daniel	5	10.Wang, Pencheng	3
Total	**75**	**Total**	**71**

The top PD/PIs by number of patent applications and awards separated by R21/R33 and SBIR/STTR funding mechanisms (Table 24) depict more patent activity within the R21/R33 funding mechanisms compared with the SBIR/STTR funding mechanisms. Under the R21/R33 funding mechanism, 33.6% (n=93) of all patent applications and awards were produced by the top 10 PD/PIs, and under the SBIR/STTR funding mechanisms, 81.2% (n=69) of all patent applications and awards were produced by the top 10 PD/PIs.

Table 24. Top Principal Investigators by Patent Applications and Awards by Funding Mechanism

PD/PI (R21/R33)	Apps and Awards	PD/PI (SBIR/STTR)	Apps and Awards
1. Shaughnessy, John	27	1. Anderson, N	20
2. Aebersold, Ruedi	18	2. Chee, Mark	12
3. Lam, Kit	11	3. Neri, Bruce	8
4. Lieber, Charles	11	4. Bogen, Steven	6
5. Heyduk, Tomasz	9	5. Battrell, Charles	5
6. Beebe, David	8	6. Nedelkov, Dobrin	5
7. Engelward, Bevin	8	7. Monforte, Joseph	4
8. Majumdar, Arunava	8	8. Wang, Pencheng	4
9. Bradley, Allan	7	9. Balgley, Brian	3
10. Jay, Daniel	6	10. Bitter, Grant	2
Total	**93**	**Total**	**69**

Patent Distribution: IMAT compared to Comparison Group Research. Of 473 Comparison Group grants, 10% (n=46) resulted in patents. This is much lower than the 21.2% of IMAT-funded grants that produced patents noted earlier. IMAT-funded research via the R21/R33 funding mechanism produced significantly

more patent applications, t(58)=-1.94, $p<.05$ than the Comparison Group via R21/R33 funding mechanisms, and IMAT-funded research via the SBIR/STTR funding mechanisms produced significantly more patent applications, t(31)=-2.18, $p<.05$, than the Comparison Group via SBIR/STTR funding mechanisms. IMAT-funded grants and the Comparison Group resulted in a similar number of patent awards. Overall, IMAT-funded research produced more patent applications, but not awards, than Comparison Group funded research, t(105)=-2.80, $p<.05$ (Table 25 and Table 26). No other group differences were detected.

Table 25. Patent Applications for IMAT and Comparison Groups

	IMAT Applications (Mean)	IMAT Applications (Max)	Comparison Applications (Mean)	Comparison Applications (Max)
R21/R33	2.2	16	1.6	5
SBIR/STTR	2.1	7	1.3	2
Overall	**2.2**	**16**	**1.3**	**5**

Table 26. Patent Awards for IMAT and Comparison Groups

	IMAT Awards (Mean)	IMAT Awards (Max)	Comparison Awards (Mean)	Comparison Awards (Max)
R21/R33	1.90	11	2.1	9
SBIR/STTR	3.7	20	1.6	4
Overall	**2.3**	**20**	**2.0**	**9**

Patent Class Comparisons. Patents are organized according to their technology orientation, which is referred to as patent classification (Battelle, 2015). Patent documentation can designate classifications such as primary or secondary, but they are not required to do so. The three most common primary patent classifications for the IMAT group were "Chemistry: molecular biology and microbiology" (n=151), "Drug, bio-affecting and body treating compositions" (n=44), and "Chemistry: electrical and wave energy" (n=30). The three most common primary patent classes for the Comparison Group were "Drug, bio-affecting and body treating compositions" (n=18), "Radiant energy" (n=8), and "Chemistry: molecular biology and microbiology" (n=6) (Table 27).

Table 27. Number of Patent Applications and Awards by Patent Class by Patent Classification

Patent Class	IMAT	Comparison
Chemistry: molecular biology and microbiology	151	6
Drug, bio-affecting and body treating compositions	44	18
Chemistry: electrical and wave energy	30	0
Chemical apparatus and process disinfecting, deodorizing, preserving, or sterilizing	20	1
Combinatorial chemistry technology: method, library, apparatus	14	0
Chemistry: analytical and immunological testing	10	3
Radiant energy	9	8
Measuring and testing	8	0
Active solid-state devices (e.g., transistors, solid-state diodes)	6	0
Image analysis	5	2
Data processing: measuring, calibrating, or testing	4	0
Optical: systems and elements	4	1
Optics: measuring and testing	4	4
Fluid handling	4	0
Electrolysis: processes, compositions used therein, and methods of preparing the compositions	4	0
Data processing: artificial intelligence	3	0
Chemistry: natural resins or derivatives; peptides or proteins; lignins or reaction products thereof	3	3
Liquid purification or separation	3	0
Compositions: coating or plastic	2	0
Compositions	2	0
Adhesive bonding and miscellaneous chemical manufacture	2	0
Electricity: measuring and testing	2	3
Classifying, separating, and assorting solids	2	0
Coating apparatus	2	0
Total	**340**	**49**

Note: Some patent applications did not report a primary patent class.

Costs of Patent Applications and Awards. As discussed previously, the IMAT program awarded significantly more funding (almost twice as much) to research grants than the Comparison Group. The number of patents produced per $100,000,000 was calculated in order to compare the IMAT and Comparison Groups. For IMAT grants, 37.9 patent awards were produced per $100,000,000, and for the Comparison Group grants, 30.1 patent awards were produced per $100,000,000. As noted earlier, patent approvals can take many years; thus, the evaluation team calculated the number of patents or applications produced per $100,000,000 as well. For IMAT grants, 117.4 patents applications or awards were produced per $100,000,000 while for the Comparison Group grants, 50.7 patents applications or awards were produced per $100,000,000.

Other Output Measures

As a condition of the grant, IMAT awardees have specified objectives, or aims, that they are expected to meet by the conclusion of the grant. Thirty-eight percent of awardees met all of their aims and 40% met most of them. Less than 20% met some of the aims and slightly over 2% did not meet any of the aims. For most grantees (80.7%), these objectives or aims remained unchanged over the course of the grant period.

Interviewed PD/PIs described some challenges to application and/or dissemination of their technology. Lack of, or limited resources was identified as a primary challenge to achieving the program aims. The most prominent resource challenge was funding; budget cuts to the IMAT program, along with sequestration cuts, impacted the overall technology development and the availability of personnel with applicable expertise. PD/PI comments also reported spending considerable time establishing preliminary data, limiting the ability to continue refinement of the technology. Some PD/PIs faced technical or scientific barriers that prevented them from being able to move forward, while others reported that preliminary findings took the research in a different direction than originally proposed. Other infrequently mentioned barriers included difficulty with institutional infrastructure, inability to obtain samples for testing, aggressive timelines, ambitious plans, multiple setbacks or delays, or loss of interest by the PD/PI. Three PD/PIs reported that at the time of the interview, there were no major challenges to report, as their grant was still ongoing.

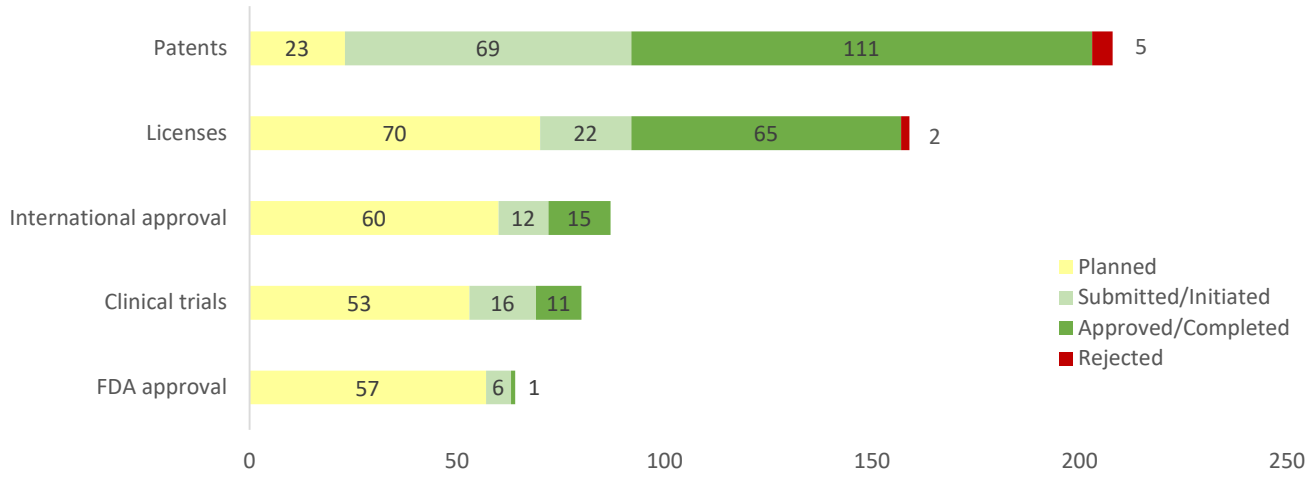
According to the web-based survey, the vast majority of awardees presented findings from their IMAT research at scientific meetings or conferences (95%), gave seminars (89%), wrote papers and publications (85%), and presented to clinical audiences (65%). About half (57%) formed strategic partnerships, and 31% established spin-off companies. Only 12 awardees reported mergers or acquisitions resulting from the IMAT award, and 4 reported public offerings.

Outcomes in Technology Development. The web-based survey also asked awardees about the following outcome areas: clinical trials, licenses, patents, and FDA or international approvals. Depending on the type of technology and its development path, these outcome areas can be critical steps to the technology development process. For each development pathway, awardees could choose “Not applicable,” “Not Planned,” “Planned,” “Submitted/Initiated,” “Approved/Completed,” or “Rejected.” Patent and licensing were the most common developmental pursuits (with only 8.4% and 15.9% indicating “Not applicable”) while FDA approval, international approval, and clinical trials were the least common (with 31.5%, 27.0%, and 26.9%, respectively indicating “Not applicable”).

Figure 30 illustrates the status of intended developmental stage (e.g., patents, licenses, international approval, clinical trials, FDA approval) of IMAT grantees and the different outcome areas (e.g., planned, submitted/initiated, approved/completed, rejected). The following calculations do not include respondents who indicated that they did not plan to achieve any of the outcomes because the outcome

areas are not applicable in these instances. Of those submitting patents, more than half had already received approval (n=111; 53%), most of the others were submitted (n=69; 33%) several (n=23; 11%) were still in the planning phase, and 2% had been rejected (n=5). Of those submitting licenses, 41% (n=65) already received approval, 14% (n=22) were submitted, 44% (n=70) were still in the planning phase, and 1% (n=2) had been rejected. Of those submitting for international approval, 17% (n=15) were already approved, 14% (n=12) had been submitted, and the majority (n=60; 69%) were still in the planning phase.

Figure 30. Status of Intended Developmental Pursuits among IMAT Grants

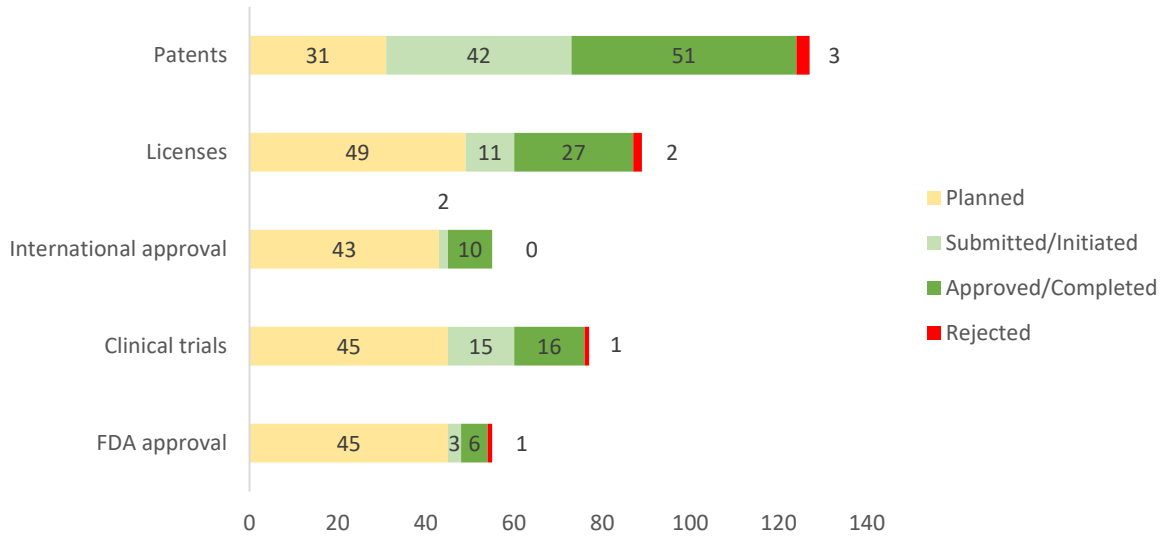


Of those who were engaged in clinical trials, 14% (n=11) had already finished, 20% (n=16) had initiated trials, and the majority were still in the planning phase (n=53; 66%). Finally, of those submitting for FDA approval, very few (n=1; 2%) had already received approval or had already submitted (n=6; 9%), and the majority were still in the planning phase (n=57; 89%).

Both those submitting patents and those applying for licenses have high rates of completion compared with the other three categories. On the other hand, the majority of respondents seeking clinical trials and FDA and/or international approval were still in the planning process. Sixty-three percent (n=135) of IMAT grantees who were surveyed indicated that they did not intend to engage in clinical trials, 68% (n=138) did not intend to seek FDA approval, 59% (n=127) did not intend to seek international approval, 36% (n=90) did not intend to obtain a license, and 24% (n=65) did not intend to obtain a patent.

The IMAT group obtained or planned to obtain a higher proportion of patents and licenses than the Comparison Group. On the other hand, the Comparison Group completed or planned to complete more clinical trials than the IMAT group (Figure 31).

Figure 31. Status of Intended Developmental Pursuits within the Comparison Group



Status of intended developmental pursuits was also examined by funding mechanism. Figure 32 and Figure 33 examine developmental pursuits for the IMAT group and the Comparison Group, respectively.

Figure 32. Status of Intended Developmental Pursuits among IMAT Grants by Funding Mechanism

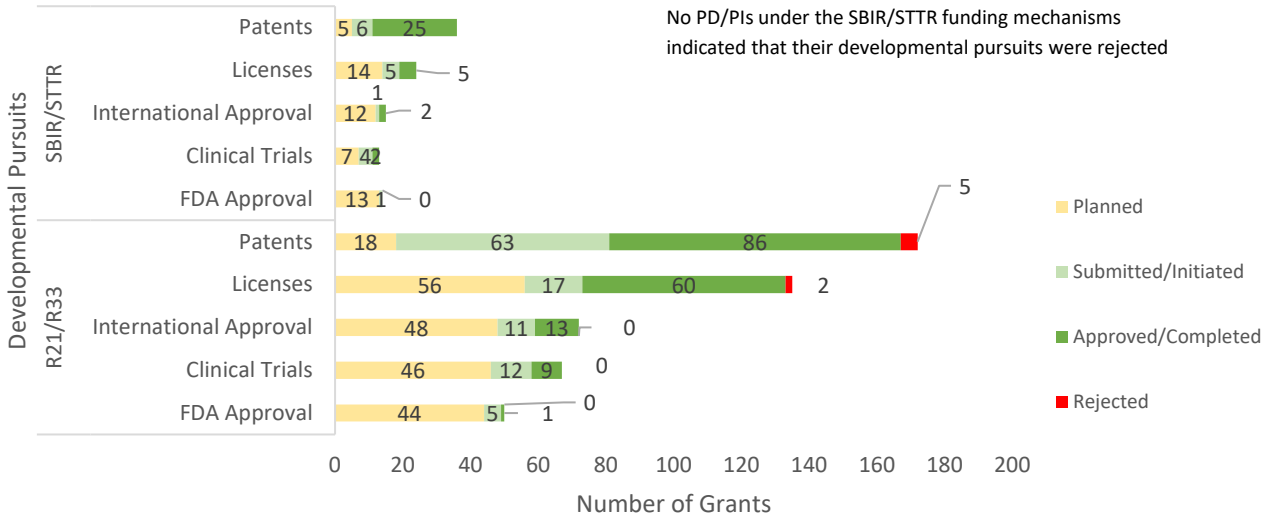
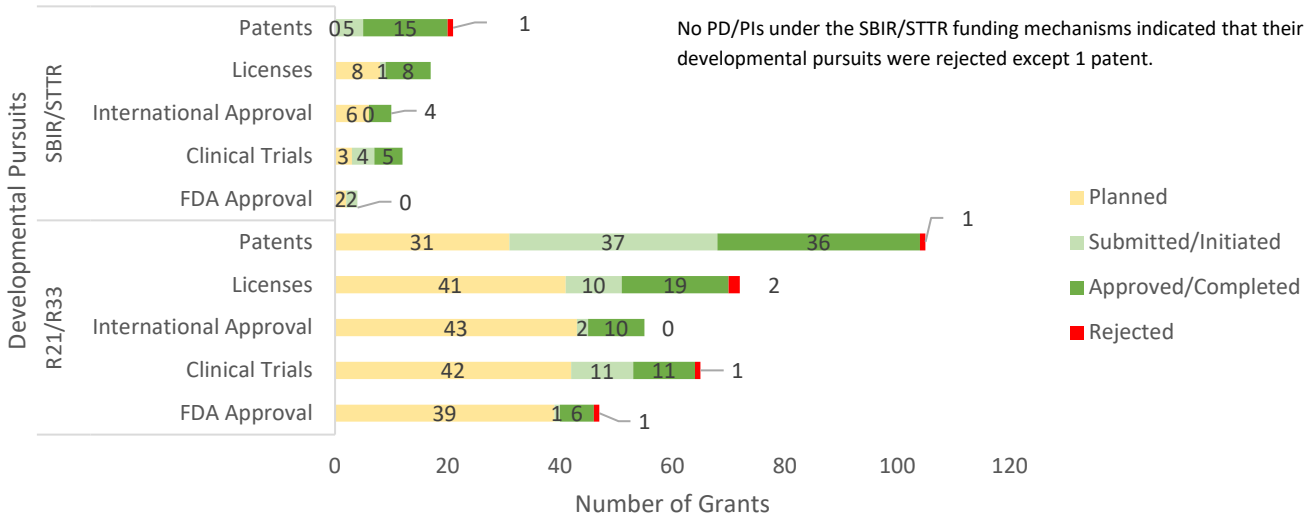


Figure 33. Status of Intended Developmental Pursuits within the Comparison Group by Funding Mechanism



There was quite a bit of overlap in the developmental pursuits. Figure 34 shows how IMAT grantees tend to pursue multiple outcomes.

Figure 34. Overlap in Developmental Pursuits within the IMAT Group

	License	Patent	Clinical Trials	FDA Approval	International Approval
License	65				
Patents	50	111			
Clinical Trials	6	8	11		
FDA Approval	1	1	0	1	
International Approval	11	15	1	1	15

In the survey, PD/PIs were also asked about institutional support for navigating and supporting the patent application process if they indicated "Planned" or higher for any of the above developmental pathways. Slightly less than 60% found their institution to be helpful or very helpful with this process. About 5% indicated their institution or organization was not helpful and 24% did not engage in the patent application or technology transfer process for their IMAT technology or methodology.

Technical Assistance. Interviewed PD/PIs were asked if and how technical assistance from NCI could have helped overcome any potential challenges that may have arisen throughout the course of the grant. The majority of the PD/PIs reported that technical assistance was not needed or would not have been helpful for their project due to the following reasons:

- The PD/PI had all necessary resources.
- Technology was too specific for technical assistance.
- Collaborators provided enough technical assistance.

Several PD/PIs stated that the only helpful technical assistance would have been additional funding and a longer grant period. Others specifically mentioned that funding cuts significantly impacted the project outcomes.

Participants reported that technical assistance from NCI could potentially be useful if PD/PIs were provided with access to existing resources and expertise from related fields. Others thought that NCI could potentially help connect them to companies or access other programs to obtain samples for technology testing.

Short-Term and Long-Term Outcomes

The IMAT program is intended to affect change in multiple outcome areas, including use of technology, ability to obtain future funding to support additional research and development, commercialization of the technology, disseminating the technology to the scientific community, use of technology in clinical trials, and further development of other technology and research. These activities are then expected to lead to the long-term outcomes of advancing the ability to diagnose and treat cancer, improving the quality and utility of biospecimens used in cancer research, and improving standards for conducting cancer research.

Funding to Advance Technology

A major section of the web-based survey was dedicated to future funding, a key outcome of the grant. Slightly over 60% of IMAT awardees (n=181) applied for funding related to the use or development of the technology during or after the initial IMAT grant award. Sixty percent of these awardees sought funding to further develop the research/technology for measurement or technical capabilities while 40% sought to apply the technology to a novel hypothesis. Out of 181 that applied for additional funding, 130 (72%) received other funding.

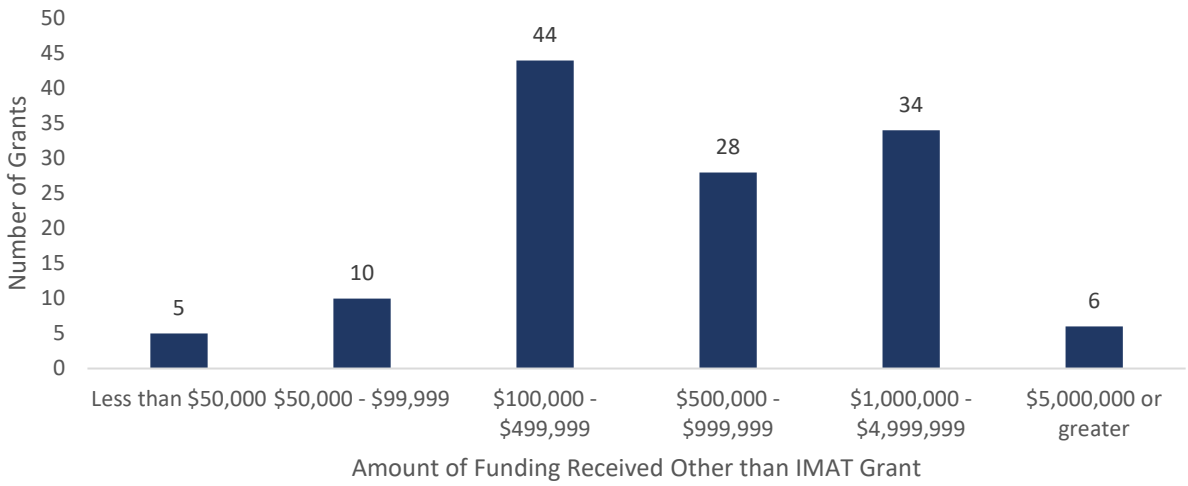
Patterns in the Comparison Group were similar to the IMAT group. Slightly less than 60% of Comparison Group awardees (n=123) applied for funding related to the use or development of the technology during or after the initial grant award. Out of 123 that applied for additional funding, 89 (72%) received other funding.

Additional Funding by Activity Code. Over 46% of R21/R33 grantees applied for and received additional funding. Less than 30% did not apply for additional funding. For SBIR/STTR IMAT awardees, slightly more than 30% applied for and received other funding. Almost 47% did not apply for additional funding.

Again, patterns for the Comparison Group were similar to those of the IMAT group. Forty-seven percent of R21/R33 grantees applied for and received additional funding, and 27% did not apply for additional funding. For SBIR/STTR IMAT awardees, slightly more than 22% applied for and received other funding. Forty-seven percent did not apply for additional funding.

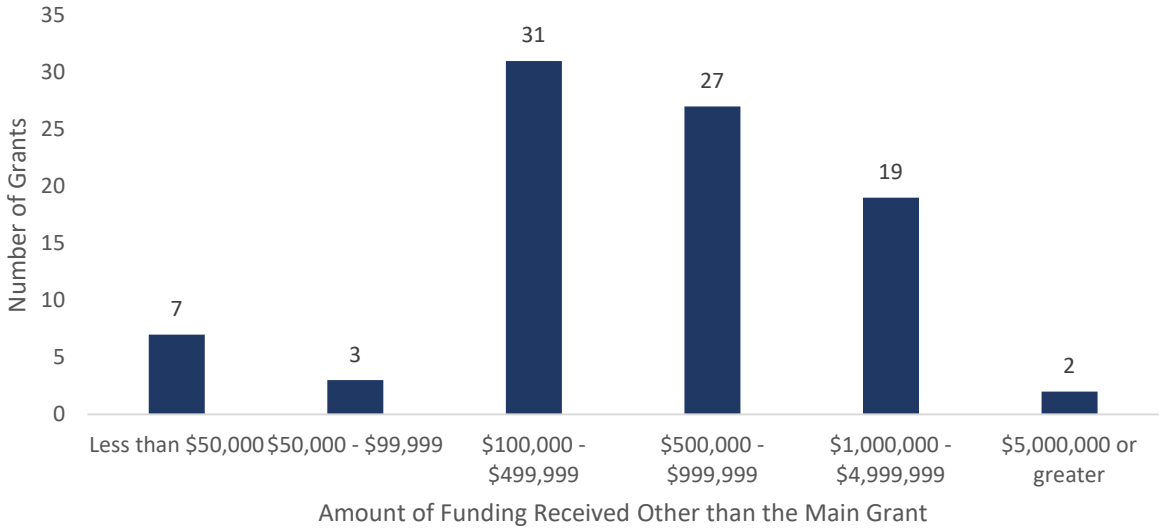
Excluding the IMAT award, those that reported receiving additional funding reported a range of funding amounts during the grant period (Figure 35). The three greatest additional funding categories were $100,000-$499,999 (n=44; 34.6%) of grants; $1,000,000-$4,999,999 (n=34; 26.8%) of grants; and $500,000-$999,999 (n=28; 22.0%) of grants. Most of the funding awarded to the grants had value between $100,000 and $4,999,999.

Figure 35. Funding Obtained During the Grant Period (Excluding the IMAT Award)



The three greatest additional funding categories were $100,000-$499,999 (n=31; 34.8%) of grants; $500,00-$999,999 (n=27; 30.3%) of grants; and $1,000,000-$4,999,999 (n=19; 21.3%) of grants). Both the IMAT and Comparison Groups obtained a range of additional funding with the $100,000-$499,999 range being the most common amount obtained by both groups (Figure 36).

Figure 36. Comparison Group Funding Obtained During the Grant Period (Other than the Main Grant)



Additional funding sources were further examined to detect any differences between the IMAT and Comparison Groups when funding mechanism was considered (Figure 37 and Figure 38). The IMAT and Comparison Groups were similar in that the PD/PIs under the R21/R33 mechanism tended to request additional funding (115 R21/R33 PD/PIs in the IMAT Group compared to 14 SBIR/STTR PD/PIs in the IMAT Group and 82 R21/R33 PD/PIs in the Comparison Group compared to 7 SBIR/STTR PD/PIs in the Comparison Group). The IMAT R21/R33 funding mechanisms tended to skew towards requesting larger amounts of money than the Comparison Group R21/R33 funding mechanism. In the IMAT Group, the

two most popular funding categories for both R21/R33 and SBIR/STTR PD/PIs were $100,000-$499,999 (35.7% and 21.4% respectively) and $1,000,000-$4,999,999 (25.2% and 35.7% respectively). In the Comparison Group, the most popular funding category for the R21/R33 PD/PIs was the $100,000-$499,999 (35.4%), whereas the SBIR/STTR PD/PIs tied between the $100,000-$499,999 and $1,000,000-$4,999,999 categories (28.6% for each).

Figure 37. Funding Obtained During the Grant (Other than IMAT Grant) by Funding Mechanism

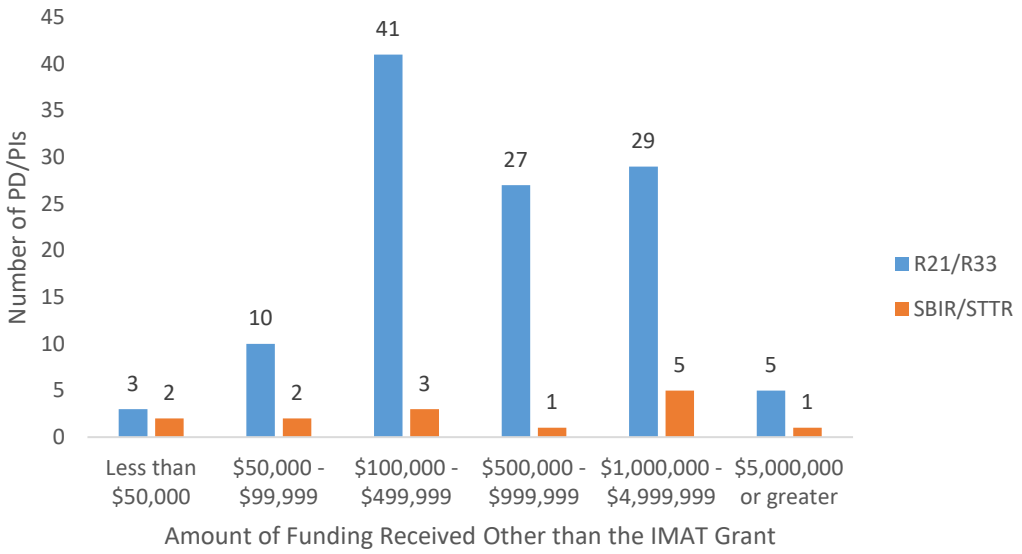
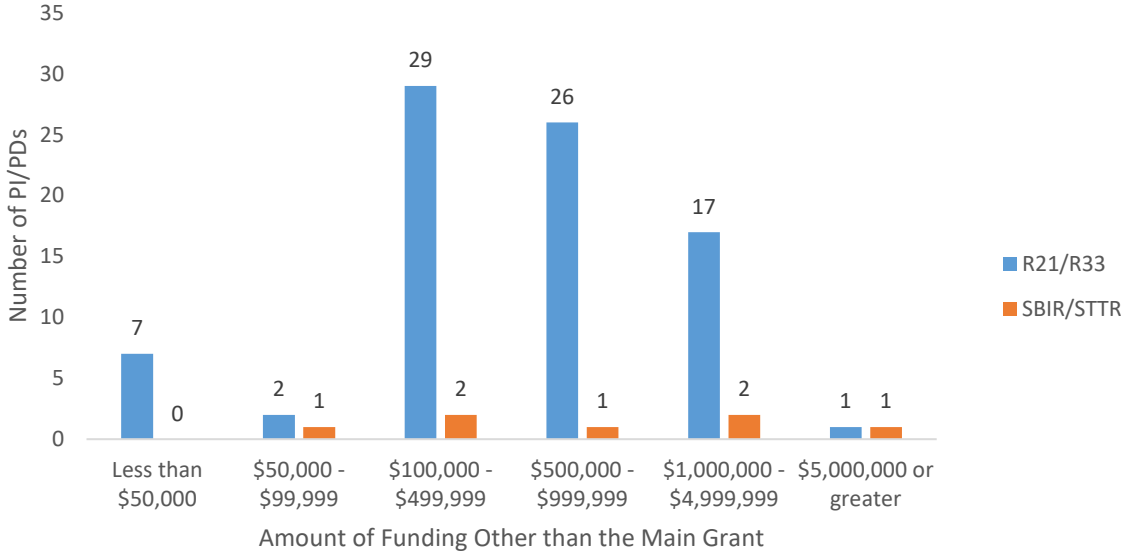


Figure 38. Comparison Group Funding Obtained During the Grant (Other than the Main Grant) by Funding Mechanism



Source of Additional Funding. Eighty percent of both the IMAT-funded group and the Comparison Group reported NIH as the largest source of additional funding. The pattern in the Comparison Group was

similar with 93% of NIH funding coming from the R21/R33 funding mechanism and 7% of NIH funding coming from the SBIR/STTR funding mechanism.

Private funding sources also represented just under a quarter of responses for both groups. For both the IMAT and Comparison Group, no PD/PIs reported receiving funding from the National Institute of Standards and Technology (NIST). The only notable difference between the IMAT awardees and the Comparison Group was that 18% of IMAT awardees, compared to less than 8% of the Comparison Group) reported receiving additional funding from the Department of Defense (DoD).

Technology Application

An important goal of the IMAT program is to encourage further use of the technologies among researchers and clinicians to help benefit cancer-relevant communities. During the interviews, PD/PIs were asked about their knowledge of practical uses and applications of their technology. Common responses included use of technology by other labs and researchers, use as a starting point for additional research, publications and presentations, and commercialization efforts.

PD/PIs reported adoption of the technology in other labs (n=12/119; 10%), as well as receiving requests from other scientists, labs, and companies to use their methods, technologies, and techniques. Additionally, participants also reported that the innovative technology has been used as the basis for both internal and external research groups. The technology has also provided a baseline for some PD/PIs to apply for additional funding to continue or expand on the technology. Other PD/PIs (n=28/119; 24%) reported technology-specific uses and methodologies that are being extended to other projects based on successful results.

PD/PIs discussed presentations and publications (n=32/119; 27%) as a key factor to extending the technology further. Participants reported that publications have led to increased citations and collaborations, and the increased exposure has helped raise more awareness about the utility of the respective technologies.

Interviewed PD/PIs reported varying levels of success commercializing their technologies (n=14/119; 12%). Most reported successful entry into commercialization, and a few PD/PIs reported that commercialization of their product is currently in progress. A few PD/PIs said that commercialization was an end goal but that barriers, including the recession, associated costs, and niche marketing, have made it difficult or impossible to commercialize the product.

PD/PIs noted a desire to commercialize but indicated multiple barriers to commercialization.

Some PD/PI comments (n=24/119; 20%) noted that the technology was not available for widespread use for a variety of reasons, including lack of follow-up funding or other resources to further the research, limitations in the findings, ongoing research, and lack of follow-up research upon completion of the grant period. The remaining comments (n=9/119; 8%) provided miscellaneous discussion about technology application.

Impact on Other Researchers. Comments from PD/PI interviews (n=17/62; 27%) described a general increase in awareness of their research among colleagues in their field, primarily through publications and presentations. PD/PI comments (n=25/62; 40%) reported technology-specific advances and the increased interest as a basis for other researchers' work. Additionally, PD/PIs said that other researchers have contacted them directly to discuss questions, collaborations, and other potentially related research projects. PD/PI comments (n=6/62; 10%) reported that their technology had been adopted or widely

used in the scientific community. One such PD/PI noted that technology adoption is a slow process in the academic world compared to the scientific field.

Some PD/PI comments (n=14/62; 23%) reported that the grant was still in progress or that the technology was in too early a stage of development to be feasible for dissemination or other application. Several PD/PIs mentioned that the research has yet to be published, limiting their knowledge of their technology's impact on other researchers.

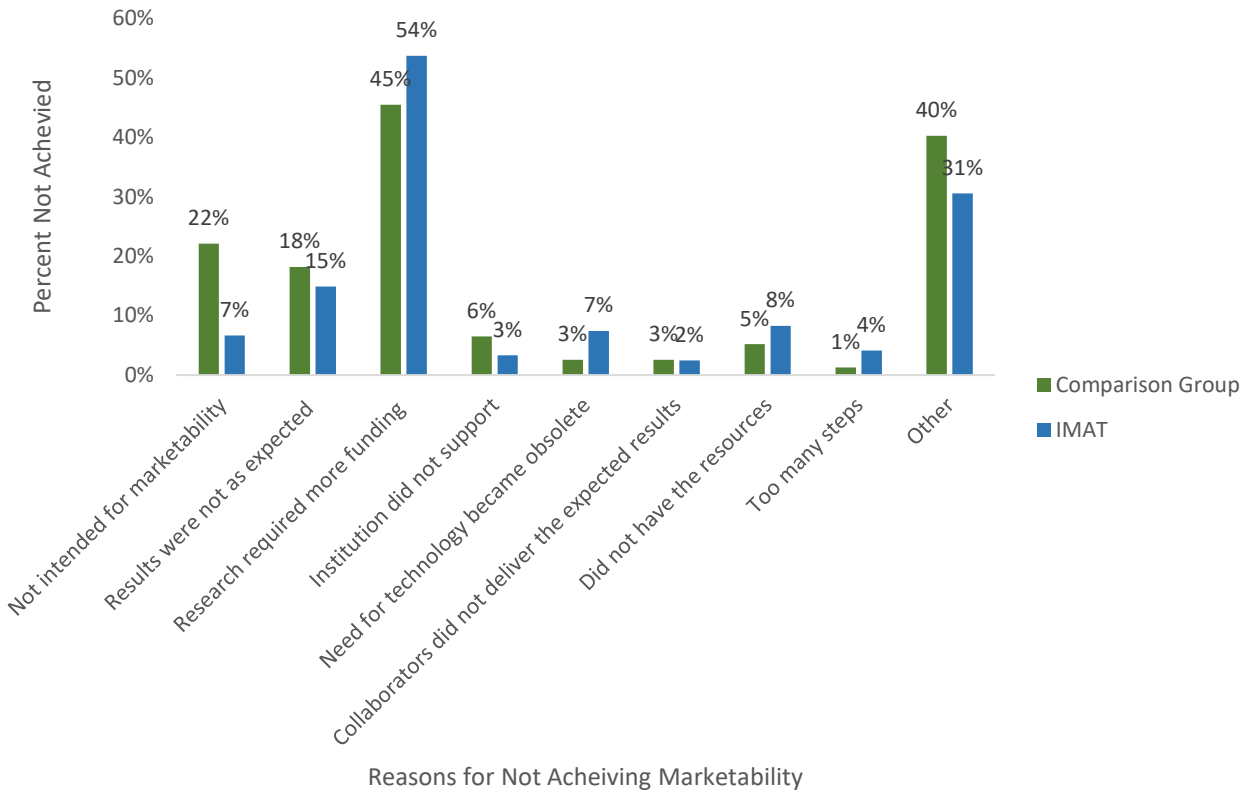
Technology Dissemination

Technology dissemination was conceived by the evaluation team as 1) the extension or further development of technology as a result of the work completed under the IMAT grant, and 2) the marketability or widely accepted use of the technology or methodology developed under the IMAT grant. Survey questions sought to identify product development and use.

Extension of Product Development. According to the survey results, 40% of IMAT awardees indicated subsequent technologies or methods had been developed as a result of their IMAT grant. This continued development generally involved the PD/PI, although almost 29% of PD/PIs reported others involved with the grant (e.g., a colleague, a co-PI, or other investigators) moved the research or technology forward without their involvement. PD/PIs were aware of the current status of less than half of these efforts, but approximately 43% noted new technologies or methods were developed as a result. Less than 10% of PD/PIs reported that the continued effort by others did not result in any new technologies or methodologies.

Marketing or Widespread Use of Product. IMAT Awardees were asked whether their research led to a marketable technology or a widely accepted methodology. Although not a major goal of the IMAT program, a slight majority (53%) indicated their research achieved this goal, while 40% indicated that their research did not achieve this goal. In comparison, 41% of the Comparison Group indicated that their research achieved marketability or wide acceptance. For the IMAT group, the most commonly cited reason for not achieving this outcome was that the research required more funds (54.6%). Fifteen percent of PD/PIs indicated the research results were not as expected, and the unexpected result prevented further development. Just under 7% of PD/PIs noted that their research was not intended to lead to a marketable technology or a widely accepted methodology. See Figure 39 for reasons the technology did not achieve marketability.

Figure 39. Reasons for Technology Not Achieving Marketability According to IMAT Grantees



Almost 30% of those who indicated that their technology did not achieve marketability also responded to the open-ended option, "Other: please specify," with almost half stating their research is still in progress (most R21 awardees). A small group reiterated a lack of funding as the problem, two stated a failure to transition to the R33, and two others reported that continued development was perceived as either too expensive or too long-term and risky. Others offered the following explanations for why their technology did not achieve marketability:

- The advent of next generation sequencing technology changed the landscape of the market and made some of the awardees' work obsolete;
- It was too difficult to obtain a patent and commercialize their products;
- There were challenges entering a competitive market;

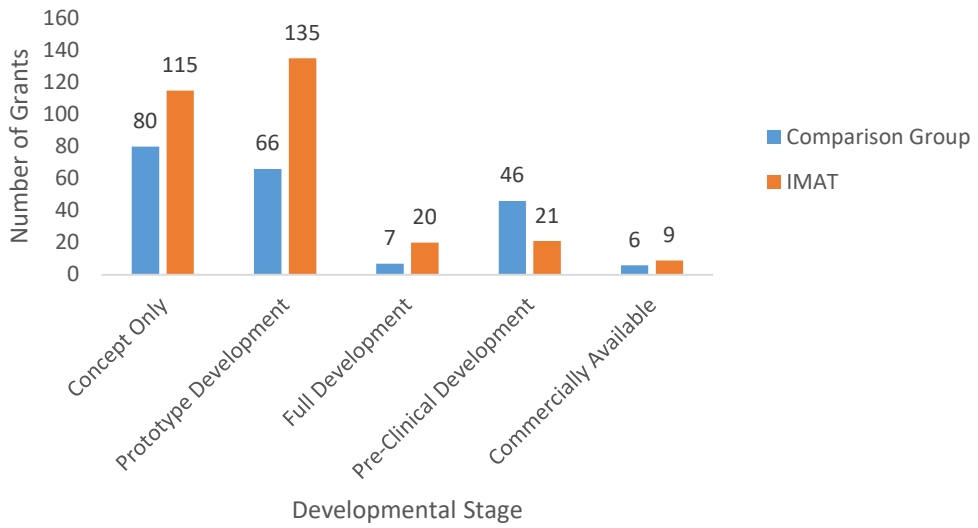
- Difficulty with or a failure of components of the technology (e.g., it was too complicated for users, it was incapable of performing a task, it was too difficult to develop software for the device);
- The field/community had either changed direction or simply failed to adopt the new technology or methodology; and
- The technology had been acquired by a company that subsequently discontinued further development [for R44 awardees].

Stages of Development. Both the R21/R33 and SBIR/STTR funding mechanism have similar two-phase development progressions. Phase I begins with the concept or prototype development stage. Phase II generally involves further development and validation. To facilitate a standardized method of assessing developmental progress among IMAT grantees, the web-based survey presented a range of categories across the development spectrum. Almost 46% of awardees (n=136) indicated their technology or methodology was ready for market or dissemination upon completion of the grant period.

PD/PIs were asked to describe the stage of development their research was in prior to the beginning of the grant, at the end of the grant, and at the time of the survey. In the survey, PD/PIs did not always answer all questions about the developmental stages; therefore, the sample sizes for those who described their developmental stage prior to the grants, at the conclusion of the grant, and at the time of the survey are not always the same.

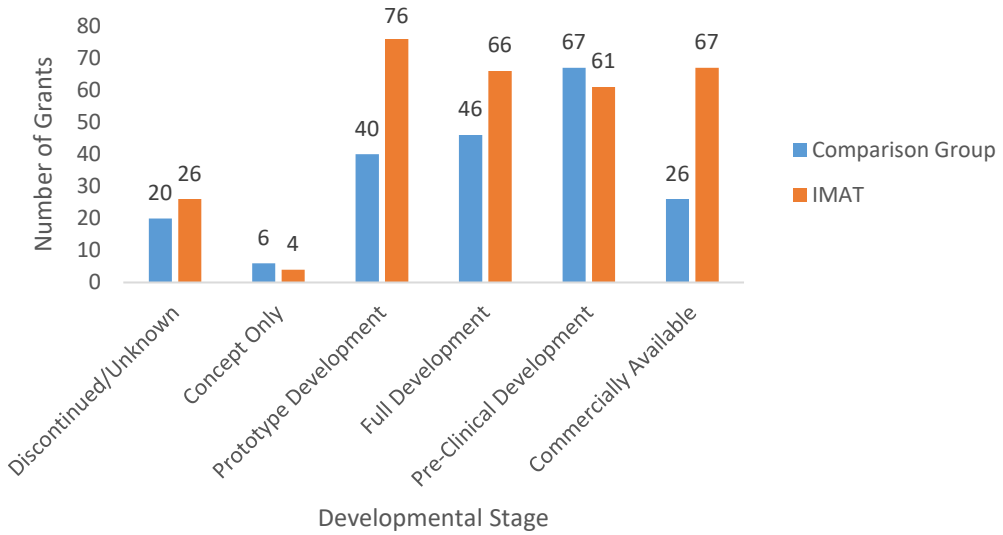
Nearly half (n=113/256; 44.1%) of the IMAT R21/R33 awardees were in the prototype development/ testing stage at the beginning of the grant, with more equal representation between the prototype development/testing stage and full development/testing stage by the end of the grant (n=91/254; 35.8%) and (n=82/254; 32.3%) respectively. The IMAT SBIR/STTR awardees followed the same pattern with half of awardees starting in the prototype development/testing stage (n=22/44; 50%) and ending in the prototype development/testing stage and full development/testing stage (n=16/45; 35.6%) and (n=14/45; 31.1%) respectively. Within each development stage, the trend seemed to be a greater percentage of awardees starting in the earlier development stage and ending in a later development stage. When compared to the Comparison Group, a greater percentage of IMAT awardees (R21/R33 and SBIR/STTR) started at the prototype development stage (n=135/300; 45.0%) while a greater percentage of the Comparison Group investigators started at the pre-clinical development stage (n=80/205; 39.0%) (Figure 40). No SBIR/STTR awardees stated that technologies were commercially available prior to funding, but many R21/R33 and SBIR/STTR awardees had progressed to commercialization by the time of evaluation (n=52/256; 20.3%) for R21/R33 awardees (n=15/44, 34.1%).

Figure 40. Development Stage Prior to Receiving Award for IMAT Awardees and Comparison Group



Changes in the stage of development for the Comparison Group were examined by funding mechanism. A greater percentage of IMAT awardees ended their grant in the prototype development or having their technology commercially available (25.3% and 22.3% respectively) compared to the Comparison Group (19.5% and 12.7% respectively). A greater percentage of the Comparison Group awardees had a technology that was discontinued or had an unknown status (9.8% compared to 8.7% among IMAT awardees).

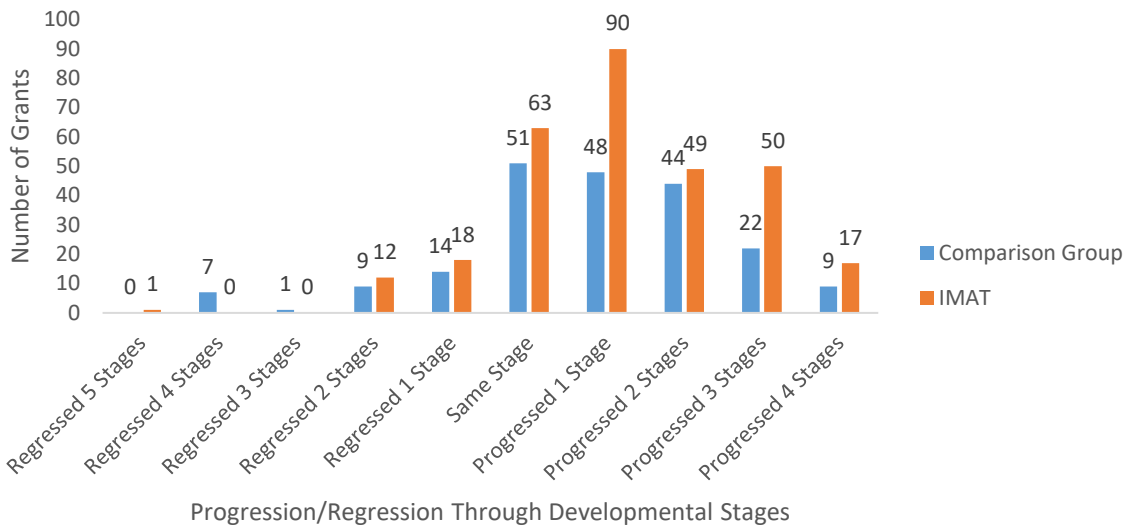
Figure 41. Development Stage after Receiving Award for IMAT Awardees and Comparison Group



Close to 70% of the IMAT awardees were able to progress at least one development stage while 10% regressed and 21% remained in the same development stage (Figure 2Figure 42). In the Comparison Group, approximately 60% of the PD/PIs progressed at least one development stage while 15% regressed and 25% remained in the same development stage. Despite having the same number of grants

regress in both the IMAT and Comparison Groups, a greater percentage of investigators regressed in the Comparison Group. There is a significant relationship between the funding mechanism and regressing in any development stage (p=0.04 using Chi-squared test), but no significant relationship between funding mechanism and staying in the same development stage or progressing in development stages. There is also a significant relationship between the funding mechanisms and stage regression among the SBIR/STTR activity codes (p=0.03 using Chi-squared) but not in the R21/R33 activity codes. A limitation to this analysis is that the number of SBIR/STTR grants that regressed is less than half of the number of R21/R33 grants that regressed, thus a more comparable sample size may yield different results.

Figure 42. Stage Progression and Regression through Developmental Stages for IMAT Awardees and Comparison Group



The patterns were similar to IMAT-funded grants within each funding mechanism, with no notable differences compared with the IMAT group.

In further examining the differences between the R21/R33 and SBIR/STTR, the evaluation team examined the differences in stages (Figure 43 and Figure 44 respectively) for IMAT and Comparison Group. These figures demonstrate that the IMAT and Comparison Groups tend to have similar percentages of PD/PIs who report their technology is commercially available at the conclusion of the grant (average 10.8% for IMAT awardees and 9.7% for Comparison Group awardees), but more PD/PIs report that the technology is in preclinical development in the Comparison Group compared to the IMAT group (average 37.1% for Comparison Group awardees and 11.4% for IMAT awardees), regardless of funding mechanism. A larger percentage of the PD/PIs in the IMAT group reported being in the prototype development (average 35.7%) or full development stages (average 31.7%) compared to the Comparison Group (average 24.0% and 18.0% respectively), regardless of funding mechanism. At the end of the grant, more IMAT SBIR/STTR awardees were in the concept only stage compared to the R21/R33 awardees, while the opposite was true in the Comparison Group. Other notable differences include more IMAT R21/R33 awardees being in the pre-clinical development and having a commercially available technology at the end of the grant compared to the IMAT SBIR/STTR awardees, while again the opposite was true in the Comparison Group.

Figure 43. Stage of Development at IMAT Grant Conclusion by Funding Mechanism

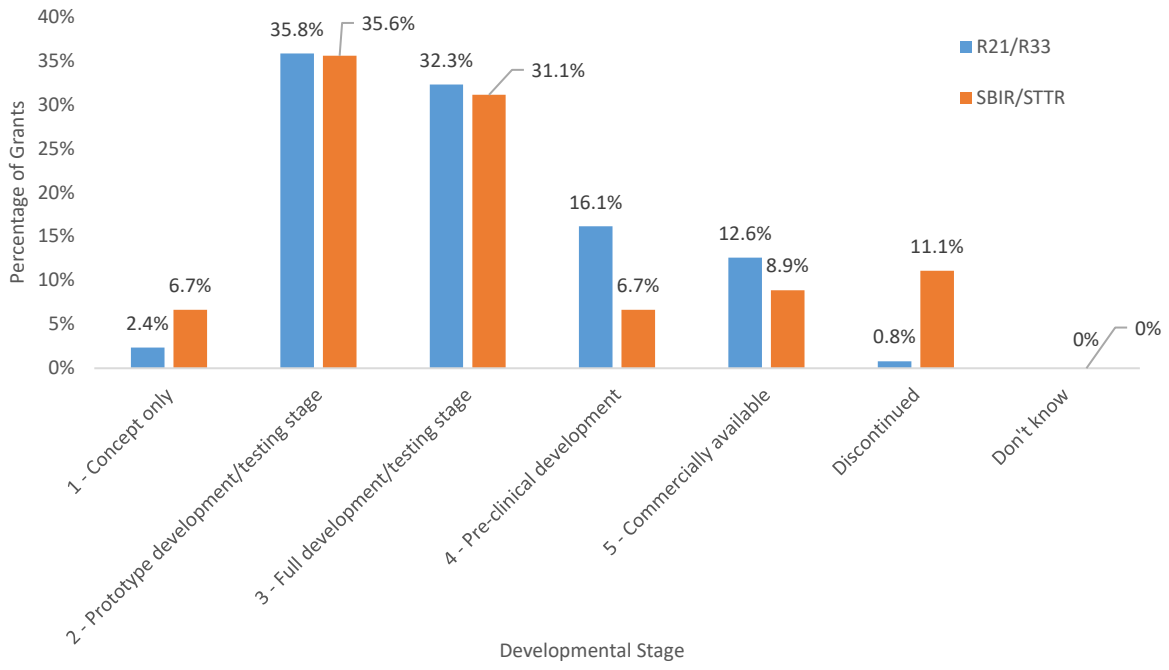
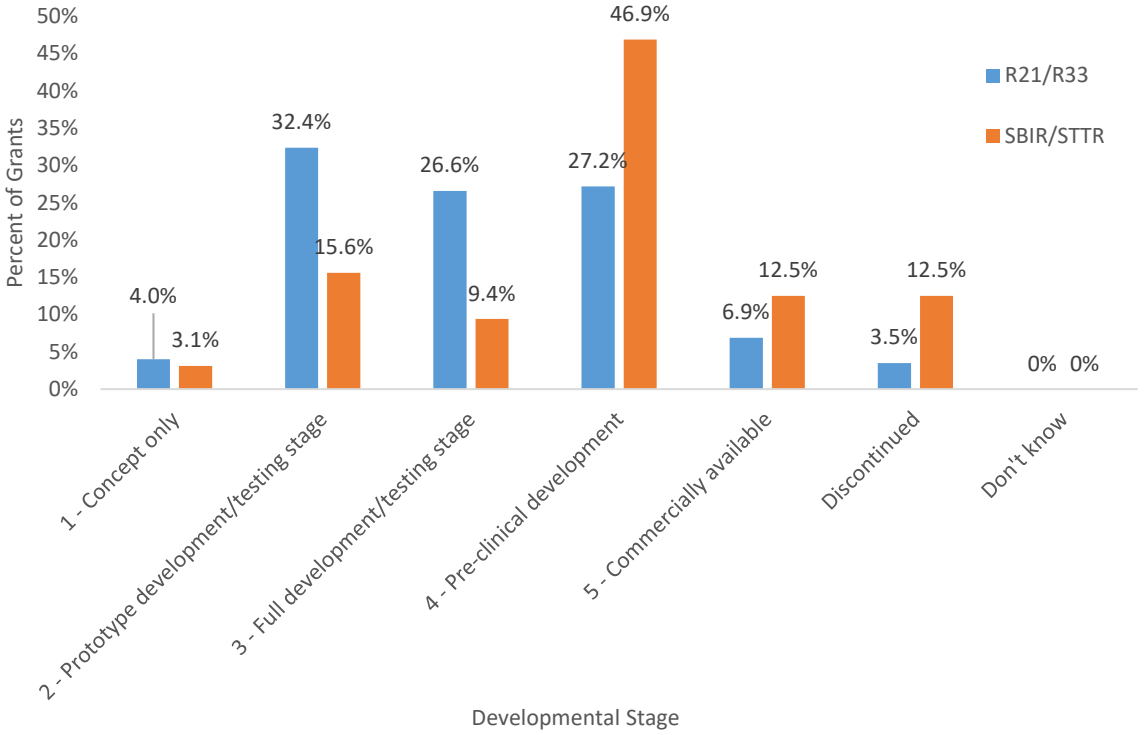


Figure 44. Stage of Development at Grant Conclusion for Comparison Group by Funding Mechanism



At the time of the study, more IMAT PD/PIs reported their technology was commercially available (average 27.2%) than the Comparison Group (average 6.4%). Other stages of development were roughly comparable between the groups (Figure 45 and Figure 46).

Figure 45. Stage of Development for IMAT Grants at Time of Study by Funding Mechanism

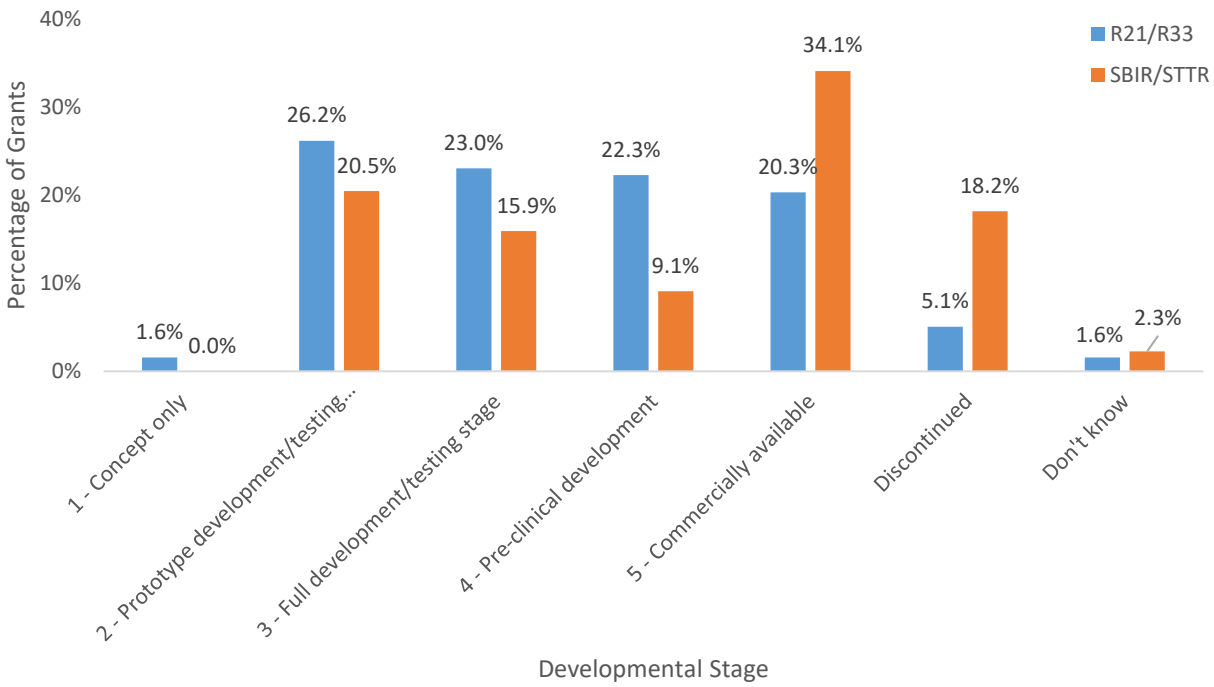
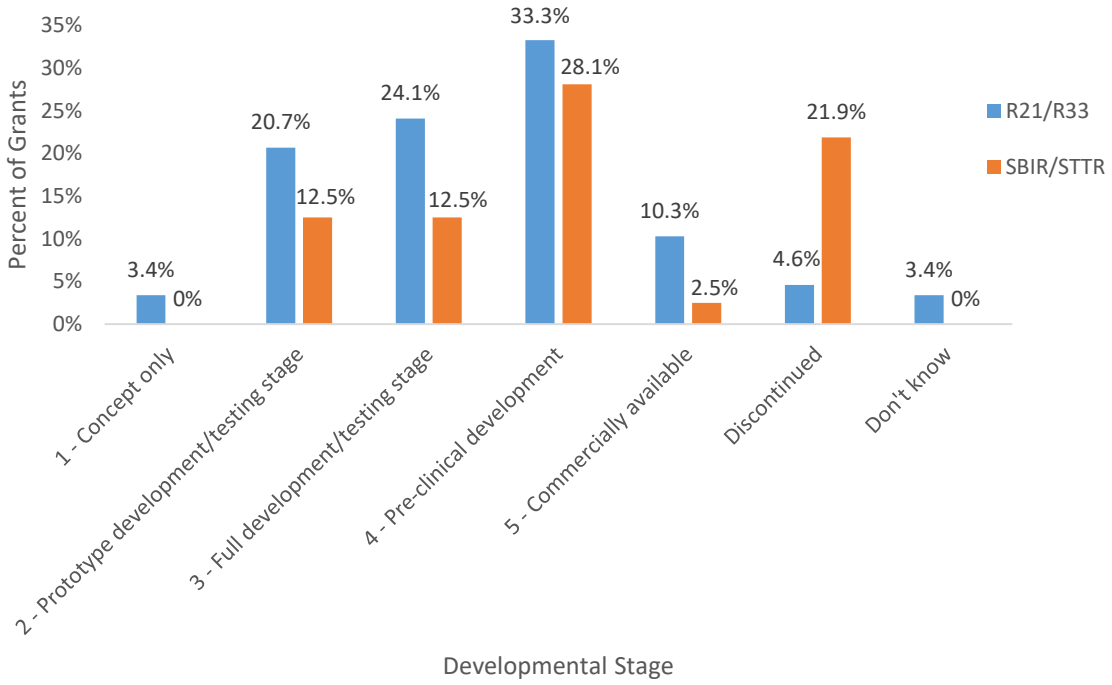


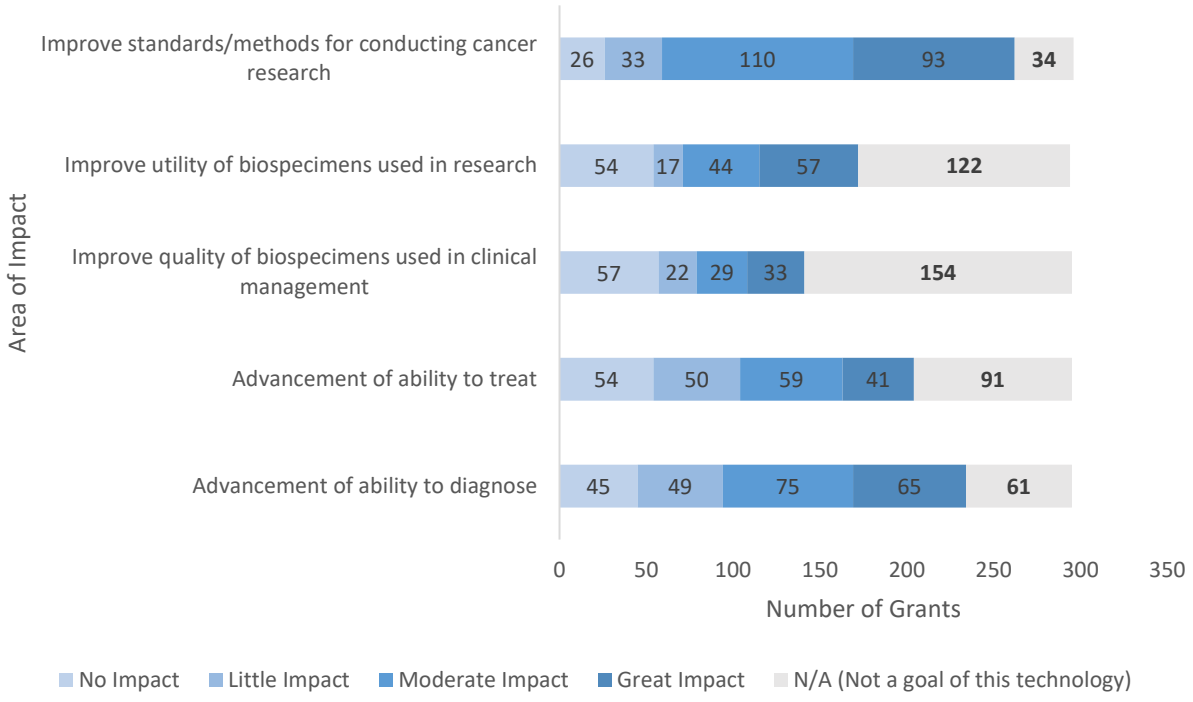
Figure 46. Stage of Development for Comparison Group at Time of Study by Funding Mechanism



Improving Research Standards and Ability to Diagnose and Treat Cancer

The survey asked PD/PIs their opinions regarding the impact of their technology on five areas of cancer research. For each area, the following options were available: no impact, little impact, moderate impact, great impact, or not a goal of this technology. The most common area of greatest impact (Figure 47) was improving the standards or methods for conducting cancer research. Thirty-one percent (n=93) indicated a great impact in this area, and close to 40% (n=110) indicated a moderate impact. Advancing the ability to diagnosis was another highly reported impactful area with 64% (n=189) of IMAT grantees indicating their technology had an impact. For IMAT grantees, the least common area of impact was the improvement of biospecimens used in clinical management. Over 50% (n=154) of awardees responding to the survey indicated it was not a goal, and less than 30% (n=84) reported impact in this area. Improving the utility of biospecimens used in research was the second least commonly reported impact with 40% (n=118) indicating between little and great impact in this area.

Figure 47. Reported Impact of IMAT-funded Technology

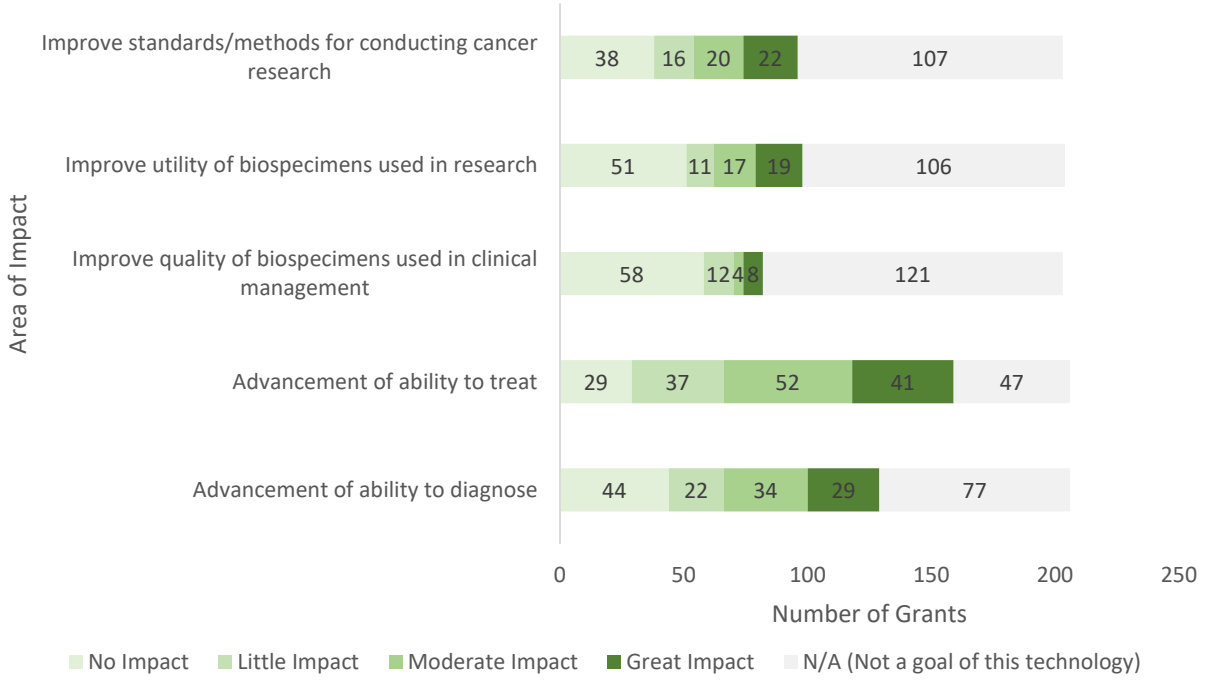


The IMAT funded grants within the BIOSP-themed area were examined separately to determine the areas of greatest and least impact. Ninety percent (n=28) of BIOSP-themed area awardees reported that the area with the greatest impact was improving the utility of biospecimens. The area of least impact was in the advancement of the ability to treat with 39% (n=12) of BIOSP-themed area awardees indicating that this area was not a goal of the technology or there was no impact.

In the Comparison Group, 63% (n=130) of grantees reported the greatest area of impact was the advancement of the ability to treat (Figure 48). Twenty percent (n=41) estimated a great impact, and 25% (n=52) estimated a moderate impact. This is in contrast to the IMAT group's greatest area of impact (improving the standards and methods for conducting cancer research) which is reflective of many of the goals of the IMAT program. Both the IMAT group and Comparison Group reported that their technologies had the least impact in the ability to improve quality of biospecimens used in clinical

management. Additionally, almost 60% (n=121) indicated improving the quality of biospecimens used in clinical management was not a goal of their technology. This may reflect the low numbers of BIOSP-themed applications within IMAT program as well as the possibility that the Comparison Group grantees seek little funding in this area.

Figure 48. Reported Impact of Comparison Group Technology



Types of Technology Produced

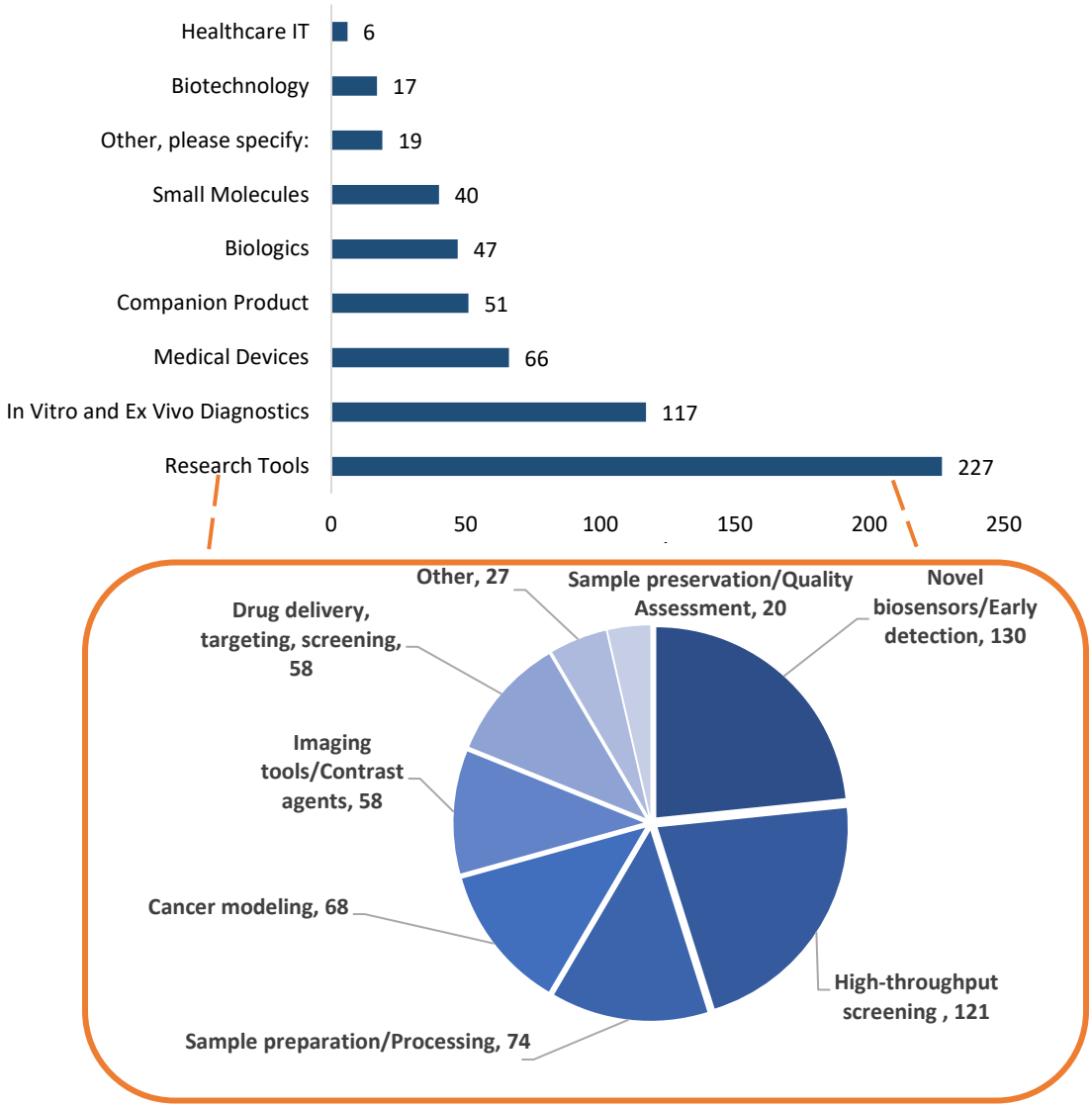
The research methodologies and technologies produced under the grant fall into eight major categories including research tools, in vitro and ex vivo diagnostics, medical devices, companion products, biologics, small molecules, biotechnology, and health IT. Drawing from survey data, the predominant area was "research tools," with almost 75% of PD/PIs indicating "research tools"[10] as the most appropriate categorization of their technology, followed by "in vitro and ex vivo diagnostics."[11]

[10] According to the U.S. Department of Health and Human Services (HHS) Public Health Service Final Progress Report Instructions, research tools are defined as "[T]he development of new or improved tools, devices, methods, and sensors to enhance laboratory or field studies on humans, animals, or any model system. This includes tools and methods that broaden the research knowledge base and for biomonitoring."

[11] According to the HHS Public Health Service Final Progress Report Instructions, in vitro and ex vivo diagnostics are defined as "[T]he use of tools (software, hardware or combinations) to identify or screen for medical conditions and determine whether specified diseases or disease processes are present in living organisms. Includes the use of these tools for non-clinical screenings and to provide insights in the work of clinicians, providers, manufacturers of equipment, and companies involved in therapies associated with disease."

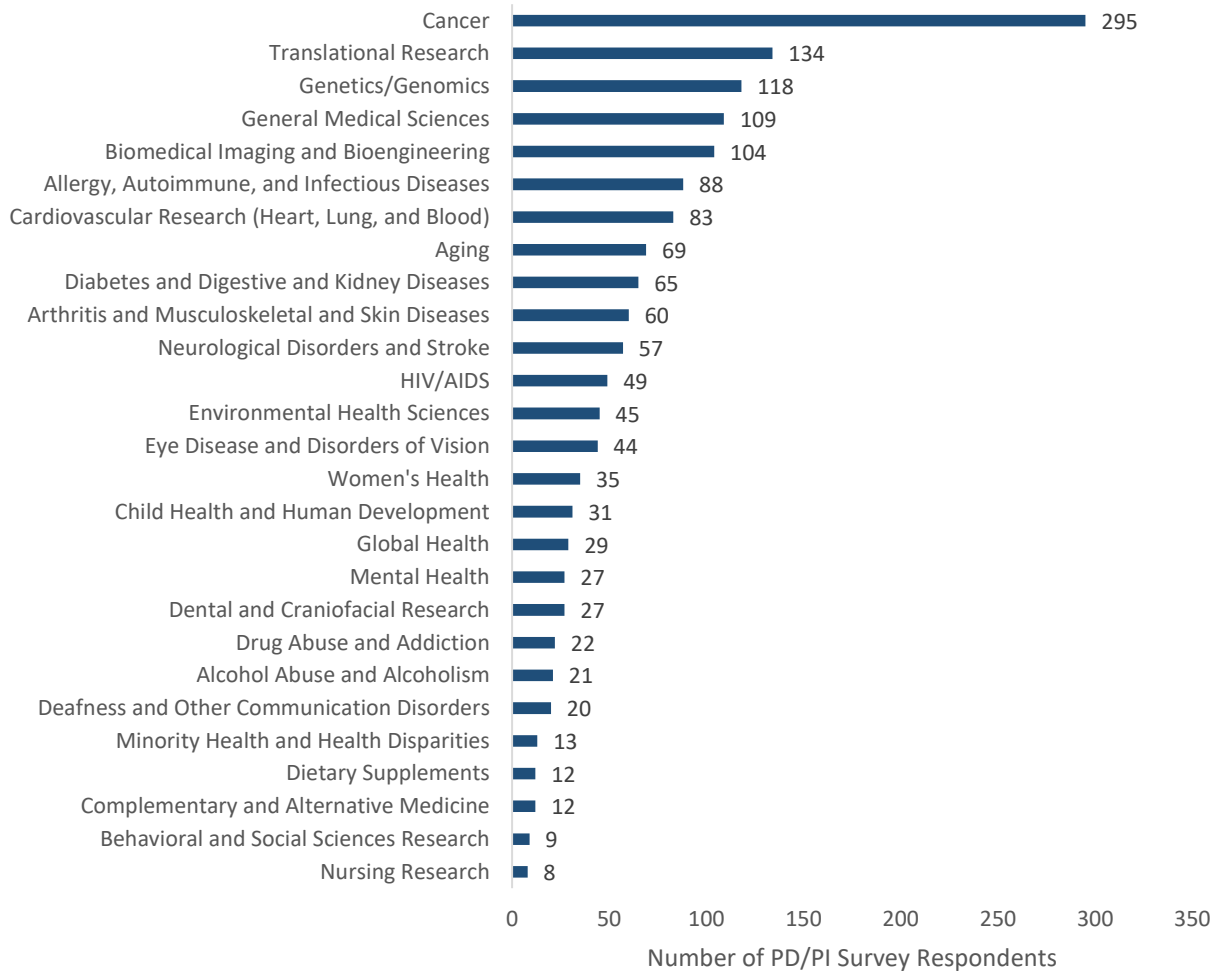
For technologies and methodologies categorized as "research tools," PD/PIs were asked to specify the type of tool or method. The survey question allowed for multiple category selection. Figure 49 provides the distribution of these data with research tools by type.

Figure 49. Type of Research Methodologies and Technologies



Survey participants were asked to further select which disease or research area to which the technologies or methodologies applied. The technologies developed from IMAT funding were primarily intended for cancer-related applications, which was expected. However, PD/PIs noted a number of other health-related areas in which their research and technologies were having, or have the potential to have, an effect. Survey participants could select all areas that applied, and these areas are presented in Figure 50.

Figure 50. Application Areas of Research and Technology

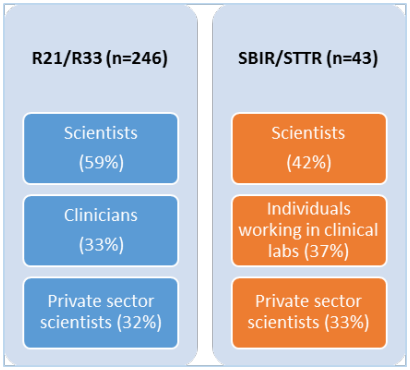


Intended Users. In an open-ended question on the survey, PD/PIs were asked to describe the intended End Users of their technology or methodology. Almost all survey responses included descriptions of more than one type of End User. Using an inductive data-driven approach, nine[12] categories emerged

[12]The nine categories are scientists, clinicians, private sector scientists, academic scientists, clinical labs, patients, the general public/individuals at risk, individuals working in regulatory agencies/government labs, and not-specified.

and were used to identify the types of End Users. Because PD/PIs identified more than one type of End User, the categories are not exclusive and do not add up to 100%.

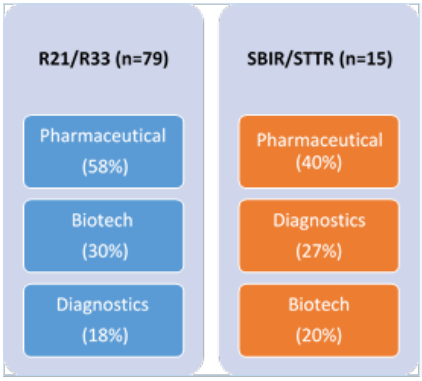
Figure 51. Types of End Users, Described by PD/PIs



The top three End User groups identified by R21/R33 grantees were "Scientists" (without a description of the context where the research would be conducted), "Clinicians," and "Private sector scientists" (Figure 51. Types of End Users). SBIR/STTR grantees also identified "Scientists" as the top group; "Individuals working in clinical labs" was the second most common group of End Users, followed by "Private sector scientists."

Private Sector Scientists. Of the 94 grantees who identified "Private sector scientists" as an End User group, the majority of R21/R33 grantees specified scientists who work at pharmaceutical companies, followed by scientists working at biotechnology firms, and scientists working at diagnostic companies (). SBIR/STTR grantees most frequently mentioned scientists working at pharmaceutical companies (but did so less frequently than R21/R33 grantees), then those working at diagnostic companies, and biotech firms (Figure 53).

Figure 52. Types of Private Sector End Users, Described by PD/PIs



Only five grantees specified that industry or commercial R&D scientists did not fit into the three categories (e.g., pharmaceutical, biotech, or diagnostics) above. Instead, they named the specific type or area of science where the technology or methodology would be used: genome-wide methylation analysis, homeland security, screening, therapeutics/treatment, diagnostics, and translational/applied.

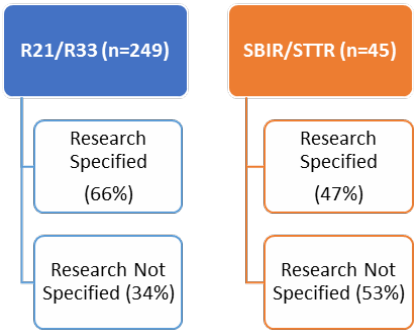
Clinicians. Of the 93 grantees who identified clinicians as End Users, about a third of all R21/R33 grantees (n=81) specified oncologists (n=25; 31%) and pathologists (n=25; 31%). About a third of SBIR/STTR grantees (n=12) specified physicians (n=4; 33%), and three (25%) named a series of other specialty areas that included gynecologists, immunologists, urologists, dermatologists, pediatricians, physicians working with infectious diseases, radiologists, and gastroenterologists.

Intended Major Uses. Survey respondents were asked to specify the intended major uses of the final technology or methodology that resulted from the grant. The evaluation team categorized responses in two steps: first, by categorizing grantee responses based on "research" as one of the major intended uses (e.g., each grantee response was categorized "Research Specified" or "Research Not Specified" to indicate whether "research" was an explicitly stated major use); then, by creating 13 categories[13] to

[13] The 13 categories of intended uses include: genetics, proteomics, treatment/therapeutics, diagnosis, drug development/discovery/screening, biomarker, detection, disease progression/prognosis, sample improvement/enrichment/processing, imaging tools or contrast agents, high throughput screening, cancer research, and other.

capture more specific intended uses, such as the general research area, general methodology, and clinical applications. All relevant categories were applied to each grantee's response.

Figure 53. Intended Major Uses



A large portion of the R21/R33 grantees reported research as one of the intended major uses of their technology; however, less than half of the SBIR/STTR grantees mentioned research (Figure 53). Most grantees who fell into the "Research Specified" category tended to describe their research in depth, and some went on to describe either the specific type of research and/or what the ultimate clinical use/patient application would be.

The evaluation team categorized survey responses into the 13 categories previously described to capture the spectrum of intended uses. The most common categories (those with more than 10% of grantees indicating that a given category was applicable to their technology) are presented in Table 28 with examples from the data. There was little difference in the distribution across the categories between the R21/R33 and SBIR/STTR grantees; therefore, the categories are reported here as the total number of IMAT grantees regardless of activity code.

Table 28. Top Categories of Intended Use

Top Categories of Intended Use[14]	IMAT Grantees N (%)
Genetics Stem cell research and applications Improvements to genetic testing, sequencing, screening, and analysis Discovery of new disease(s) Isolation, detection, and identification of rare mutations Identification of disease source	68 (23.1)
Proteomics Identification of protein-protein interactions Drug development through the discovery of new targets Isolation and quantification of protein complexes from tissues (pathology samples) Accurate detection/quantification of protein expression and modifications	38 (12.9)
Treatment/Therapeutics Monitoring/informing optimal therapy Personalized/individualized therapy Developing vaccinations Surgical procedures Therapeutic anti-cancer antibodies Stem-cell therapeutics	36 (12.2)
Diagnosis Early diagnosis Medical, non-invasive, point-of-care, and clinical diagnostics Detection of circulating tumor cells (CTCs) Improving sensitivity of diagnostic tests	34 (11.6)
Drug development/discovery/screening Identification of novel targets Screening and discovery of novel agents Understanding mechanisms of action Drug delivery techniques	31 (10.5)
Biomarker Discovery Quantification Validation Identification	28 (9.5)

[14] Less-common categories include: detection (8.2%), disease progression/prognosis (8.2%), sample improvement/enrichment/processing (7.8%); imaging tools or contrast agents (6.5%); other (6.1%); high throughput screening (5.1%); and cancer research (3.4%).

End User Use of Technology

End User interviews were conducted to assess experiences with technology developed by others through IMAT funds, and the general impacts of the technology on cancer research and/or clinical care. Twenty-two End Users representing nine IMAT-funded technology types were interviewed about their roles related to the technology, how they found out about the technology, the technology's current uses, the importance of the technology, and the overall impact on public health as a result of the technology.

Role Related to Technology. End User interview participants were asked to describe their role as it related to the IMAT-funded technology. End Users represented a range of positions, including post-docs, researchers, and laboratory heads. The post-docs and researchers used the technology in their daily research, whereas the laboratory heads oversaw projects that used the technology but had a range of experiences with personal use of the technology.

Five End User comments (n=5/20; 25%) specifically discussed their background and fields of research, noting that the technology aligned with the specific research they had conducted in the past or were conducting at the time of the interview. Several End Users (n=5/20; 25%) described a collaborative research role with other scientists or users. Some End Users (n=4/20; 20%) described being employed by a company that uses or markets the technology while others (n=6/20; 30%) described working in a lab that has adopted the technology. In addition to laboratory uses, End Users discussed other types of companies that use, or have some investment in the technology, including medical device companies, a technology test site, and a tissue bank. As one End User stated:

> *"I came on board as a consultant, because as a protein biochemist I have a lot of assay development knowledge. I was brought on board to evaluate the fit of this technology for specific application, trying to fit a specific market…"*

Awareness of Technology. End Users were asked to describe how they found out or became aware of the technology. Some End User comments (n=2/18; 11%) did not specifically describe how they found out about the technology, but mentioned that the technology was related to their previous work and fit nicely with their research goals. Other End User comments (n=4/15; 22%) described learning about the technology through literature or scientific publications. As one End User stated:

> *"We had a research question, we wanted to analyze mutations, and so we went through the scientific literature and looked for methods available. We came across COLD-PCR which was interesting to us and seemed like it would work best for our research question."*

Some End User comments (n=3/18; 17%) were exposed through conferences or symposiums and two of these modified the technology to better suit their needs. End User comments (n=4/18; 22%) also described learning about the technology through work with other scientists who were using the technology themselves or who suggested the technology as a useful mechanism for the End User's research. Other End Users' comments (n=4/18; 22%) described knowledge of the technology through their institutions and one End User (n=1/18; 6%) became aware of the technology through investors of a startup company.

Current Use of Technology. End Users were asked to describe the current use of their respective technology types. End Users described a variety of current research projects using the technology. The majority of comments about current use were very specific to the respective technologies (n=10/29; 34%) and indicated it was in use on current research projects (n=7/29; 24%). Two End User comments

(n=2/29; 7%) described collaborating with external research groups to provide appropriate samples or specimens for research. Some End User comments (n=3/29; 10%) described modifying the original protocol or intent of the technology in order to better fit the needs of their research. Other End User comments (n=3/29; 10%) specifically identified the technology as a basis to support grant applications. As one participant stated:

> *"I've used it to support a grant application of my own, an R01 from NIGMS [National Institute of General Medical Sciences]. It's almost entirely on this technology, applying it to a number of diseases."*

Some End Users responded with comments about previous uses of the technology. One End User comment (n=1/29; 3%) described conducting previous validation studies or testing to ensure that the technology met scientific standards for continued use. Another End User (n=1/29; 3%) described using the technology to provide and distribute material samples to other researchers. Finally, two End Users (n=2/29; 7%) reported that they are no longer using the technology, so they did not have any information to provide about current technology use.

Importance of the Technology. End Users were asked to describe the extent of the importance, or critical nature, of the technology. The majority of End User comments (n=10/21; 48%) said the technology was crucial and that research could not otherwise be conducted, while others said that the technology maximized efficiency. Some End User comments (n=6/21; 29%) described the technology as useful and efficient but not critical. The general consensus was that cancer research had been going on prior to the technology development and that while the technology is helpful and interesting, research would continue on with or without the technology. One End User stated:

> *"I wouldn't say it's critical because critical would imply that if you don't have it, everything will collapse. So I wouldn't describe it as critical because we could live without it. But I think it adds significant value to research."*

Finally, the remaining End User comments (n=5/21; 24%) provided specific examples of how the technology was useful to their current research (e.g., isolating circulating tumor cells to research ovarian cancer).

Public Health Impact. End Users were asked to described public health advantages of the technology. Comments (n=7/25; 28%), described potential impacts such as increased accuracy of the research, reduction of materials and/or research costs, time-saving factors for researchers, and scalability for use on larger projects in the future.

As one End User, who worked in a lab using the technology and helped develop the equipment further, said:

> *"By maximizing the resources, not only are we more efficient generally, but we are getting the opportunity to touch more research projects, provide more samples, and therefore, hopefully move scientific discoveries along at a faster rate."*

End Users (n=3/25; 12%) noted the technologies could also help increase knowledge and improve targeting tumors. In turn, this would increase the understanding of disease progression, shorten drug development timelines, and lead to more individualized therapy for patients. Some End User comments (n=2/25; 8%) recognized the technology was in early stages of development and too early to identify the general impacts on public health; however, they speculated the impacts could be significant.

Similarly, some End Users (n=5/25; 20%) did not have a clear image of how public health was currently impacted by the respective technologies, but provided insight into the potential impacts of the technology. The key theme to emerge was the potential impact on cancer treatments due to increased knowledge of disease progression and outcomes:

> *"I have chosen to use this technology for more development and research. I am using it on human samples, but the conclusions have not been made yet. There is potential here, though, to impact cancer diagnosis and treatment."*

Several End Users (n=5/25; 20%) said that their research was enhanced as a result of the technology because it allowed them to do more with less and with increased reliability, such as performing research with less tissue, thus allowing more research with the same amount of tissue. The remaining End User comments (n=3/25; 12%) had difficulty describing or predicting public health impacts.

Additional Thoughts. Some participants voluntarily provided additional thoughts, ideas, and suggestions related to the technologies. There was a general consensus the technologies are important and it is an exciting time for cancer research. Two End Users mentioned the high value of the technology but recognized the fragility that is attached to new or innovative products. One End User was concerned that the product might become hard or impossible to obtain due to limited distribution or further technological improvements. The End User mentioned that increased funding to help ensure the continued availability of the technology would be helpful. Another End User suggested that NIH should encourage researchers to use and validate new methods and publish the results:

> *"If NIH can push people…to publish their methods, it's important. Otherwise, it becomes a niche technology that only a few labs can do. The only way it becomes widely respected is if undergrads can start replicating it. In this respect, microfluidics has work to do because it's not too easy to find out very nice protocols in low resource settings."*

Additional Program Feedback

Comparison Group

The evaluation team sent the web-based survey to the Comparison Group under the pretext of evaluating technology development grants at NIH. Similar communication was made with IMAT grantees under the pretext of evaluating technology development grants under their IMAT grant. Although the survey questions were the same for both groups, comparisons between the two study groups may be biased because of survey communications.

The majority of Comparison Group grantees (n=46; 72%) offered positive feedback about their respective programs, but not as frequently as their IMAT peers (72% compared with 83% respectively). Comparison Group grantees made fewer broad statements of support, and more frequently provided specific feedback about the significance of funding for advancing their technology. The Comparison Group also appeared more critical of their respective programs (28% provided negative feedback compared with 9% of IMAT grantees). Most negative comments revolved around a lack of funding or a failure to transition from the R21 to R33 phase. As one awardee noted below:

> *"The RFA was excellent, and directly in line with a major biomedical need. However, the R21/33 transition phase was opaque, and disappointing. Despite meeting or exceeding all milestones and having the most publications in press of any of the R21 projects at the time of renewal (per* NIH RePORTER*) the R33 phase was not granted, cutting off funding with a very short period of notice. This hampered planned extension of the project, and caused a lot of problems with*

support of postdoctoral researchers employed on the project. Feedback on the failings of the R33 application was not provided, making it difficult to re-frame the proposal for other NIH funding streams." (R21 Awardee)

The Comparison Group grantees suggested more funding be allocated to innovative and high-risk technology development.

IMAT Program Feedback

Through an open-ended question on the web-based survey, IMAT grantees were given an opportunity to provide overall feedback for the IMAT program. Responses were categorized into three groups: support, criticism, and moving forward. Out of the 126 IMAT PD/PIs who provided a response to the survey, 119 responded to this question.

Support

Many IMAT grantees (n=102; 86%) expressed gratitude, appreciation, and support for the IMAT program. The PD/PIs emphasized the importance of the program for advancing their research, calling IMAT funding "seminal," "critical," "crucial," "essential," and a means to "catalyze subsequent commercial success." Eleven PD/PIs described significant successes that illustrate ultimate IMAT program goals.

> *"This award was seminal in developing this technology at a key point where it was very fragile and had minimal acceptance and skepticism in the user community. This award permitted the technology to be developed into an approach that was robust and reliable. Since then I have personally received $5-10 million in Federal awards using this technology, and dozens of other laboratories have received Federal and other awards as well. Certainly over 100 papers have been published (50 in my lab) using these and follow-on approaches. Major papers in* PNAS *[Proceedings of the National Academy of Sciences] and* Nature *have come out of my lab and a recent paper in* Science *just came out where the technology was used without my involvement. NSF [National Science Foundation] has awarded millions of dollars to build facilities to further develop and deliver this technology to a national user community. Dozens of labs now routinely use these methods and are training the next generation. We continue to receive funding to further develop the technology. I have a spin-out company that does CRO work for pharma companies (using the basic technology) in the pre-clinical development space that provides essential services to develop biologic drugs." (R21 Awardee)*

Three themes were common as PD/PIs described valued outcomes or aspect of the program:

- Continued growth of technologies through subsequent non-IMAT funding sources (e.g., NIH [R01 mechanism], NSF, the Office of Naval Research, and private foundations);
- Proliferation of IMAT-funded technologies; and
- Facilitation of a community of scientists interested in innovative technology development, which fosters collaboration.

Five PD/PIs specifically stated their research would not have been possible without IMAT funding; two PD/PIs were early investigators at the time they received funding from the IMAT program and attribute their initial career success to the IMAT program.

Criticism

Eleven PD/PIs (9%) noted dissatisfaction with, or offered criticism of, the IMAT program related to the following funding, program structure, or administrative issues:

- Reduced capacity to meet specified milestones due to budget cuts and sequestration (n=2)
- Disagreement and confusion over their failure to transition to the R33 (n=2)
- Insufficient time to complete milestones under the R21 (n=2)
- Failure to secure further funding through any grant mechanism post-R21 (n=2)[15]
- Discretionary authority of NIH staff to order audits places private firms that are potentially unfamiliar with NIH rules and regulations at high financial risk when accepting IMAT funding (n=1)
- Lost time and resources due to a lack of knowledgeable reviewers and program staff (n=1)
- A frustrating application process (n=1)

Moving Forward

Eighteen grantees (15%) specifically called for continuation of the IMAT program, and 12 suggested that it be expanded to ensure that a particular technology's development reaches viability (e.g., that technologies are implemented in clinical settings, and that the support is sufficient to attract investors). Grantees suggested the introduction of a follow-up R33/R01 mechanism and the allowance of one renewal opportunity as potential methods for creating a more sustainable approach.

> *"The IMAT program is valuable because it supports projects where technology development, rather than hypothesis testing, is central. However, such projects often do not generate the preliminary data needed to apply for [a] hypothesis-testing R01 grant. Consequently, IMAT projects, unless they are further supported by IMAT (extremely competitive) become "one-way dead-end streets." (R21 Awardee)*

One PD/PI suggested that IMAT fund riskier projects, but the consensus of survey respondents was for less emphasis on the degree of novelty and a greater emphasis on the degree of impact (e.g., increased funding for translational and clinical research). Overall, investigators agreed that innovative and high risk technology development with a high degree of impact are important for moving cancer research forward.

> *"History has taught us that step functions in the advancement of scientific knowledge (and the utilization of this knowledge to diagnose and treat human disease) almost always reflect the introduction of new, enabling technologies. It is critical for the NIH to support the development of these technologies, and the IMAT program serves a critical purpose in achieving this objective." (R33 Awardee)*

[15] In neither instance did the grantees provide additional contextual information that would have enabled the evaluation team to determine whether this was a critique of the IMAT program.

Conclusions

The evaluation team found a number of interesting patterns from the mixed-methods analysis of archival data, web-based survey data, and PD/PI and End User interviews.

Summary of the Findings

Initial Investment

Since 1998, the IMAT program has released a total of 77 FOAs and has received a total of 5,055 application submissions. Of these applications, 705 were awarded; the majority of applications were submitted and awarded to the R21/R33 mechanism and the IMAT thematic area. IMAT grantees predominantly described their technology or methodology as "Research Tools" or "In Vitro and Ex Vivo Diagnostics." IMAT-funded technology or methodologies most commonly pertained to the following disease or research areas: "Cancer," "Translational Research," "Genetics/Genomics," "General Medical Sciences," and "Biomedical Imaging and Bioengineering." Appendix L presents a full list of funded technologies by stage of development.

PD/PIs were asked about the application submission process and responded that it was straightforward, clear, well-thought out, and well-suited to their goals and ideas. In particular, PD/PIs praised the use of milestones in the application process because the milestones helped to keep them on track during the grant period. The PD/PIs had similarly high praise for the review process stating that reviewers seemed knowledgeable and well-suited to IMAT.

PD/PIs were asked whether they contacted IMAT staff during the application process or during the grant period, and almost all responded affirmatively. They overwhelmingly stated that NCI staff were extremely helpful, encouraging, and responsive to questions. They felt that program staff were especially useful in helping to frame ideas to fit IMAT standards, generating ideas, and providing advice, indicating that the IMAT staff is integral to continuing to advance IMAT-funded research.

PD/PIs were asked whether they would have applied for other funds if they had not received their IMAT grants, and some indicated that they would have applied for other NIH funds while others would have applied for funding outside of NIH. Interestingly, many replied that they would not have applied for other funds because other mechanisms would not have been appropriate for a variety of reasons. As PD/PIs indicated that there was no preceding technology or methodology for their idea, these findings indicate that IMAT fills a very specific niche in cancer research that encourages cutting-edge, innovative research. Appendix K provides a list of preceding technologies that served as the basis for IMAT-funded technologies and methodologies.

PD/PIs discussed the usefulness of the PI meetings, largely stating that the meetings were useful, interesting, and good for networking. PD/PIs also stated that the meetings were well-managed and were helpful in continuing to move IMAT-funded technologies forward. PD/PIs had several suggestions for improving the meetings, including more formal and informal interaction times, a larger variety of talks and attendees, and increasing the amount of follow-up after the meetings. These findings indicate that PD/PIs viewed the meetings as an important avenue for advancing their research and networking with others.

Program Activities

PD/PIs were asked via web-based survey and interview about their experiences with the IMAT program. Interactions with the program staff were positive and generally resulted in improved research plans that either placed the proposed research into the context of the broader community, or narrowed the

proposed research to ensure the end result (if successful) would be useful. Specifically, the annual IMAT conference was perceived as a valuable opportunity to meet like-minded innovators and potential collaborators. It was also valued for stimulating fresh perspectives or new ideas and for providing opportunity to troubleshoot and gather feedback from respected peers. A handful of IMAT grantees explained that one of the overall benefits of the program was its capacity to continue fostering a community of innovative biomedical researchers. Learning about alternative funding sources was also an important outcome for a small portion of grantees.

PD/PIs were queried about their experiences with institutional support. Overall, most PD/PIs found their institutions to be supportive with infrastructure only. However, some felt that their institutions were not particularly helpful in any way, and a few found their institutions to be extremely supportive. Specifically, grantees who relied on their institutions for support during the patent application process found their institution helpful or very helpful. PD/PIs sometimes found that the institution impeded their research by showing a lack of care or imposing significant constraints and rules.

These findings indicate that IMAT staff are helpful to a significant degree in aiding grantees with scientific advancement, but that the institution also makes a difference. A helpful institution can provide critical support to help advance the research and potentially improve outcomes.

Short-, Medium-, and Long-Term Outcomes

Funding to Advance Technology. Innovation investment is risky because there are no guarantees of success; however, more than half of grantees reported their research had led to marketable technology or widely accepted methodology. Forty percent reported an extension or further development of their technology as a result of the work completed under the IMAT grant. Further development of work often included patents, licensing, international or FDA approval, and clinical trials. By far, the two most common pursuits were patents and licensing while FDA approval was the least common developmental pursuit. Therefore, PD/PIs with IMAT-funded research intend to continue extending the technologies that they initially developed with IMAT funds, particularly by obtaining patents and licenses.

Technology Use. As expected, most of the major uses identified by IMAT grantees involved research (mostly genetics and proteomics), but when describing ultimate, long-term uses, grantees also named specific patient applications that included therapeutics, diagnosis, and disease-progression monitoring. Grantees described End Users as scientists, clinicians (primarily oncologists and pathologists), individuals working in clinical labs, and private sector scientists working for pharmaceutical, biotech, and/or diagnostics companies.

As already mentioned, slightly more than half of IMAT grantees reported that their technology had achieved marketability or wide acceptance, while the remaining grantees indicated their technology had not achieved this. The majority of those grantees indicated that their technology did not achieve marketability or wide acceptance because their research required more funding while some stated that their research was not intended to lead to wide acceptance or marketability. In addition to these findings, grantees also noted the following reasons for not achieving marketability: they did not have the knowledge or resources to achieve the marketing stage; the need for their technology became obsolete before the marketability stage; too many steps were required to get to the marketability stage; they did not have the support of their institution; and collaborators did not deliver the expected results.

This evaluation provided a unique perspective into the use and application of technologies developed with IMAT funding after the technologies had been commercialized. End Users were interviewed regarding their use of technologies developed using IMAT funding, and overall, they were impressed with the technologies produced. They expressed sentiments that the technologies were instrumental in

moving cancer research forward. In particular, End Users largely described the technologies as critical or very important to improving public health. Since End Users who are not part of the IMAT program recognize the benefits of these technologies, it appears as though IMAT is continuously funding state-of-the-art research that will significantly impact cancer through an array of external sources.

Technology Dissemination. Almost all IMAT grantees used traditional means to disseminate research results. The vast majority presented findings at scientific meetings or conferences, gave seminars, and wrote publications. Grants within the IMAT program have produced a large number of publications and patents, with 2,054 unique published manuscripts and 361 distinct patent applications/awards made between 1999 and 2013. There were significant statistical differences indicating that IMAT-funded researchers published more manuscripts with higher impact factors and a higher average number of citations than Comparison Group researchers, and most of these differences were found when examining publications using the R21/R33 funding mechanisms compared to the SBIR/STTR funding mechanisms. Furthermore, under the R21/R33 funding mechanisms, IMAT-funded research resulted in more patent applications and subsequent awards than Comparison Group research. Few differences were found when assessing IMAT and Comparison Groups under the SBIR/STTR funding mechanisms. These findings indicate that IMAT-funded research results in higher levels of productivity than Comparison Group research, under the R21/R33 funding mechanisms. Additionally, the IMAT-funded grants resulted in more patents and publications per $100,000,000 than the Comparison Group. Based on analysis, the investment in IMAT funding has resulted in the advancement of technology through publications and patents, and they appear to be cost-effective.

Stage of Development. The evaluation team examined both IMAT Group and Comparison Group stages of development by funding mechanism, and both groups were at similar stages of development prior to the grant, at the conclusion of the grant, and at the time of the web-based survey. Responses were evenly distributed across time points and across stages of development. There were no differences, indicating that technology development may progress similarly by funding mechanisms (R21/R33 vs. SBIR/STTR) regardless of whether the research was IMAT-funded or not.

Self-reported long-term impact. IMAT and Comparison Group PD/PIs reported a few differences in the long-term impacts of their technologies, and these differences reflect the goals of the IMAT program to improve cancer technologies. The IMAT group reported the greatest area of impact as being the improvement of standards and methods for conducting cancer research, while the greatest area of impact among Comparison Group PD/PIs was the advancement of the ability to treat. Both groups reported the least impact in the area of improving the quality of biospecimens used in clinical management.

Recommendations

Value of the IMAT Evaluation

In the survey questionnaire, the PD/PIs were asked to report on the areas in which their technology had the least and most impact. Overall, IMAT grantees reported that the greatest area of impact was improving standards and methods for conducting cancer research, and the area of least impact was reported as improving the quality of biospecimens used in clinical management. These data suggest that the IMAT program provides significant contributions to cancer research. When the BIOSP-themed area was examined separately, the area of greatest impact was improving the utility of biospecimens used in research. These data suggest further that the BIOSP-themed area is a unique part of IMAT funding that helps to provide impactful research in biospecimen research.

While the survey and archival data provided insight into a number of different populations, the PD/PI interviews uncovered information not otherwise available. PD/PIs provided key advantages of the IMAT program that were not evident based on other data collection sources. For example, PD/PIs stated that their research would not have been funded, or even submitted, because there were no other existing funding mechanisms that would consider non-hypothesis driven research. PD/PIs described the IMAT program as the only program that would fund risky, innovative research. In fact, many PD/PIs said that they would not even consider seeking alternative funding mechanisms if they did not receive IMAT funding. Those who said they would have sought alternative funding streams said that it would be challenging and the likelihood of being awarded a grant from another agency would be slim. PD/PIs noted that NCI staff were instrumental in helping grantees solve problems and achieve aims and milestones. In turn, this assistance helped grantees progress throughout the course of the research and helped further the technologies and the science.

This evaluation provided a unique perspective into the use and application of the technologies developed with IMAT funding. End Users expressed sentiments that the technologies were instrumental in moving cancer research forward. In particular, End Users largely described the technologies as critical or very important with the potential to lead to improved public health outcomes through innovative research. While the PD/PIs could describe anticipated impacts, the End Users were able to provide experiences, challenges, and insight to public health impacts that were not otherwise available from archival data or the PD/PI survey and interviews.

Recommendations for the IMAT Program

Throughout the process of completing the evaluation, the evaluation team identified some themes that emerged that might be useful to consider for possible future iterations of the IMAT program:

- IMAT staff should continue the extensive, responsive communication with PD/PIs
- PI meetings should be enhanced to include a wider variety of presentations, expansion of attendee types, more time for interactions between participants, and meeting-follow-up activities
- NCI should provide additional resources to help with technology commercialization (e.g., workshops)
- Overall, proportionately more SBIR/STTR grants are associated with patents than R21/R33 grants
- The BIOSP-themed area fulfills a specific niche because PD/PIs with these grants report the highest impact in the area of improving the utility of biospecimens in research while PD/PIs with other grants consider biospecimen research to be their area of least impact
- NCI should consider re-introducing coupled awards in a limited way to meet the needs of individual projects that may benefit from a united approach

Recommendations for Future Evaluations

In order to improve future evaluation and monitoring of the outcomes of the IMAT program, Ripple Effect observed several areas that could improve data collection efforts in the future and potentially become embedded within program reporting.

- Asking PD/PIs to include the formal and alternative names of their technologies in the progress reports (in a semi-structured field) to aid future evaluations
- Asking PD/PIs to include downstream development (licensing, adoption by others, subsequent NIH Funding) in as standardized a fashion as possible in annual reporting

- Incorporating the stages of technology development in annual reporting (or as a supplemental survey that could be used for regular program monitoring/final reporting)
- Encouraging grantees to consistently use NIH's RePORTER to obtain more data on fields such as number of text mentions for "news" and "media" or number of press releases and "Research Matters" submissions
- Increasing enforcement of compliance of grantees with Bayh-Dole Act to report government-funded inventions to iEdison
- Exploring the potential to quantify measures of risk for future awards to explore differences, perhaps within the review process
- Continuing to use certain survey items to more consistently measure "progress" across grantees
- Continuing to use the Comparison Group strategy to add richness and rigor for evaluations
- Continuing to use End User interviews to identify successes, challenges, and impact from external sources
- Incorporating known, or potential End User contacts as a standardized question in progress reports (in a semi-structured field if possible) to aid future evaluations and help improve End User recruitment

Appendix A – References

American Evaluation Association. Research, Technology & Development Evaluation Topical Interest Group. (2015). *Evaluating outcomes of publicly-funded research, technology and development programs: Recommendations for improving current practice* (Version 1.0). Washington, DC: American Evaluation Association.

Centers for Disease Control and Prevention. Program Performance and Evaluation Office (PPEO). (2012 May 11). Introduction to program evaluation for public health programs: a self-study guide. Step 1: engage stakeholders. Retrieved from http://www.cdc.gov/eval/guide/step1/index.htm

Dodson, S. (2016). Better Capturing NIH's Outcomes and Impact. NIH Division of Science Policy Coordination, Collaboration, and Reporting. Presentation to the Extramural Program Management Committee. [PowerPoint slides].

Glynn, R. W., Chin, J.Z., Kerin, M.J., & Sweeney, K. J. (2010). Representation of cancer in the medical literature: A bibliometric analysis. *PLoS ONE, 5*(11): e13902. doi:10.1371/journal.pone.0013902

Grueber, M., & Tripp S. (2015). *Patents as proxies revisited: NIH innovation 2000 to 2013*. Columbus, OH: Battelle Memorial Institute.

Hall, B. H., Jaffe, A., & Trajtenberg, M. (2001). *The NBER patent citations data file: Lessons, insights and methodological tools* (Working Paper 8498). Retrieved from National Bureau of Economic Research website: http://www.nber.org/papers/w8498

Harhoff, D., Narin, F., Scherer, F. M., & Vopel, K. (1997). Citation frequency and the value of patented innovation (Discussion Paper FS IV 97–26). Retrieved from the Zentrum für Europäische Wirtschaftsforschung website: http://ftp.zew.de/pub/zew-docs/dp/dp2797.pdf

Hirsch, J.E. (2005). An index to quantify an individual's scientific research output. Proceedings of the National Academy of Sciences of the United States of America, 102(46):16569–72. PMID: 16275915. Retrieved from http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1283832/pdf/pnas-0507655102.pdf

IEEE Board of Directors. (2013 September 9). Appropriate use of bibliometric indicators for the assessment of journals, research proposals, and individuals. Retrieved from http://www.ieee.org/publications_standards/publications/rights/ieee_bibliometric_statement_sept_2013.pdf

Kalutkiewicz, M. J., & Ehman, R. L. (2014). Patents as proxies: NIH hubs of innovation. *Nature Biotechnology*, *32*(6), 536–537. doi:10.1038/nbt.2917

Lawrence, P.A. (2003). The politics of publication. *Nature*, *422*(3):259-61.

Moodley, J., Singh, V., Kagina, B. M., Abdullahi, L., & Hussey, G. D. (2015). A bibliometric analysis of cancer research in South Africa: Study protocol. *BMJ Open*, *5*:e006913. doi:10.1136/bmjopen-2014-006913

National Cancer Institute. (n.d.a). National Cancer Institute Alliance for Nanotechnology in Cancer. Mission and Goals. Retrieved from http://nano.cancer.gov/about/mission/

National Cancer Institute. (n.d.b). Cancer Imaging Program. Retrieved from http://imaging.cancer.gov/aboutcip

National Cancer Institute. (n.d.c) Cancer Imaging Program. Research Funding Current CIP Initiatives. Retrieved from http://imaging.cancer.gov/researchfunding/fundingopportunities/currentcip

National Cancer Institute (2015a). Innovative Molecular Analysis Technologies. Retrieved from http://innovation.cancer.gov

National Cancer Institute (2015b). Innovative Molecular Analysis Technologies. IMAT patent trends. Retrieved from http://innovation.cancer.gov/about/outputs/patents/trends.asp

National Cancer Institute. Innovative Molecular Analysis Technologies. (2015c). IMAT publication trends. Retrieved from http://innovation.cancer.gov/about/outputs/publications.asp

National Cancer Institute. (2015d, July 1). SBIR Development Center. Funding section SBIR-IMAT. Retrieved from http://sbir.cancer.gov/funding/opportunities/sbirimat

National Institutes of Health. (n.d.). Biomedical Information Science and Technology Initiative Home Page. Retrieved from https://www.bisti.nih.gov/

National Institutes of Health. (2012, March 22). Research Portfolio Online Reporting Tools (RePORT). Research project success rates by NIH institute for 2014. Retrieved from http://report.nih.gov/success_rates/Success_ByIC.cfm

National Institutes of Health. (2013a, May 15). Mission. Retrieved from http://www.nih.gov/about/mission.htm.

National Institutes of Health. (2013b, September 12). Grants and Funding. NIH Exploratory/Developmental Research Grant Award (R21). Retrieved from http://grants.nih.gov/grants/funding/r21.htm.

National Institutes of Health. (2014, September 29). Innovative Research in Cancer Nanotechnology (IRCN) (U01) PAR-14-285. Retrieved from http://grants.nih.gov/grants/guide/pa-files/PAR-14-285.html.

National Institutes of Health. (2015a, January 23). About the NIH Common Fund. Retrieved from https://commonfund.nih.gov/about.

National Institutes of Health. (2015b, September 18). High-Risk Research Overview. Retrieved from http://commonfund.nih.gov/highrisk/overview.

National Institutes of Health. (2015c, February 5). What are SBIR and STTR Programs? Retrieved from https://sbir.nih.gov/.

National Institutes of Health. (2015d, August 18). Development of Innovative Informatics Methods and Algorithms for Cancer Research and Management (R21) PAR-15-334. Retrieved from http://grants.nih.gov/grants/guide/pa-files/PAR-15-334.html.

Rothwell, J., Lobo, J., Strumsky, D., & Muro, M. (2013). *Patenting prosperity: Invention and economic performance in the United States and its metropolitan areas*. Retrieved from Brookings Institution website: http://www.brookings.edu/~/media/Research/Files/Reports/2013/02/patenting-prosperity-rothwell/patenting-prosperity-rothwell.pdf

Thonon, F., Boulkedid. R., Delory, T., Rousseau, S., Saghatchian. M., van Harten. W., . . . Albert, C. (2015). Measuring the outcome of biomedical research: A systematic literature review. *PLoS ONE*, *10*(4): e0122239. doi:10.1371/journal.pone.0122239

Appendix B – The IMAT Program

NCI launched the Innovative Molecular Analysis Technologies (IMAT) program in 1998 to support the development of highly innovative technologies to advance cancer research and clinical care capabilities. IMAT supports the development of technologies in clinical, laboratory, and epidemiological research. To avoid duplication of effort with the Biomedical Information Science and Technology Initiative (BISTI) and Cancer Imaging Program (CIP), IMAT's scope specifically excludes new bioinformatics or statistical techniques, tools, and/or software solutions as well as whole body or *in vivo* imaging technologies. Awards through IMAT are made through a variety of mechanisms. To date, the IMAT program has issued 540 R21 and R33 awards and 165 SBIR and STTR awards, supporting roughly 500 unique technology platforms and approximately 509 PD/PIs. See Table 29 for a list of all FOAs released from 1998 to 2013.

Table 29. FOAs from 1998 to 2013 with Release and Expiration Dates

FOA Number	FY Released	Posted Date	Expiration Date	Thematic Area	Funding Mechanism
PAR-98-066	1998	5/8/1998	5/8/2001	IMAT	SBIR/STTR
PAR-98-067	1998	5/8/1998	5/8/2001	IMAT	R21/R33
PAR-99-100	1999	5/14/1999	3/22/2001	IMAT	R21/R33
PAR-99-101	1999	5/14/1999	3/22/2001	IMAT	SBIR/STTR
PAR-99-102	1999	5/14/1999	3/22/2001	EMAT	R21/R33
PAR-01-104	2001	5/31/2001	7/22/2003	IMAT	R21/R33
PAR-01-105	2001	5/31/2001	7/22/2003	IMAT	R21/R33
PAR-01-106	2001	5/31/2001	7/22/2003	EMAT	R21/R33
PAR-01-107	2001	5/31/2001	7/22/2003	IMAT	SBIR/STTR
RFA-CA-05-002	2005	12/17/2003	10/19/2004	IMAT	R21/R33
RFA-CA-05-003	2005	12/17/2003	10/19/2004	EMAT	R21/R33
RFA-CA-05-004	2005	12/17/2003	10/19/2004	BIOSP	R21/R33
RFA-CA-05-006	2005	1/7/2004	10/19/2004	IMAT	SBIR/STTR
RFA-CA-05-007	2005	1/7/2004	10/19/2004	EMAT	SBIR/STTR
RFA-CA-06-004	2006	12/8/2004	10/19/2005	BIOSP	R21/R33
RFA-CA-06-002	2006	12/9/2004	10/19/2005	IMAT	R21/R33
RFA-CA-06-003	2006	12/9/2004	10/19/2005	EMAT	R21/R33
RFA-CA-06-005	2006	12/16/2004	10/19/2005	IMAT	SBIR/STTR
RFA-CA-06-006	2006	12/16/2004	10/19/2005	EMAT	R21/R33
RFA-CA-07-006	2007	1/26/2005	9/27/2006	IMAT	SBIR/STTR
RFA-CA-07-001	2007	12/8/2005	5/27/2006	IMAT	R21/R33
RFA-CA-07-003	2007	12/8/2005	5/27/2006	BIOSP	R21/R33
RFA-CA-07-002	2007	12/8/2005	5/27/2006	EMAT	R21/R33
RFA-CA-07-006	2007	1/26/2006	9/27/2006	IMAT	SBIR/STTR
RFA-CA-07-007	2007	1/26/2006	9/27/2006	IMAT	SBIR/STTR
RFA-CA-07-008	2007	1/26/2006	9/27/2006	EMAT	SBIR/STTR

FOA Number	FY Released	Posted Date	Expiration Date	Thematic Area	Funding Mechanism
RFA-CA-07-009	2007	1/26/2006	9/27/2006	EMAT	SBIR/STTR
RFA-CA-07-010	2007	1/26/2006	9/27/2006	IMAT	SBIR/STTR
RFA-CA-07-011	2007	1/26/2006	9/27/2006	IMAT	SBIR/STTR
RFA-CA-07-015	2007	5/2/2006	9/22/2006	IMAT	R21/R33
RFA-CA-07-016	2007	5/2/2006	9/22/2006	IMAT	R21/R33
RFA-CA-07-017	2007	5/2/2006	9/22/2006	EMAT	R21/R33
RFA-CA-07-018	2007	5/2/2006	9/22/2006	EMAT	R21/R33
RFA-CA-07-019	2007	5/2/2006	9/22/2006	EMAT	R21/R33
RFA-CA-07-023	2007	5/2/2006	9/22/2006	BIOSP	R21/R33
RFA-CA-07-024	2007	5/2/2006	9/22/2006	BIOSP	R21/R33
RFA-CA-07-022	2007	5/3/2006	9/22/2006	BIOSP	R21/R33
RFA-CA-07-033	2007	1/4/2007	9/28/2007	IMAT	R21/R33
RFA-CA-07-034	2007	1/4/2007	9/28/2007	IMAT	R21/R33
RFA-CA-07-035	2007	1/4/2007	9/28/2007	EMAT	R21/R33
RFA-CA-07-036	2007	1/4/2007	9/28/2007	EMAT	R21/R33
RFA-CA-07-037	2007	1/4/2007	9/28/2007	BIOSP	R21/R33
RFA-CA-07-038	2007	1/4/2007	9/28/2007	BIOSP	R21/R33
RFA-CA-07-039	2007	1/4/2007	9/29/2007	IMAT	SBIR/STTR
RFA-CA-07-040	2007	1/4/2007	9/29/2007	IMAT	SBIR/STTR
RFA-CA-07-041	2007	1/4/2007	9/29/2007	EMAT	SBIR/STTR
RFA-CA-07-042	2007	1/4/2007	9/29/2007	EMAT	SBIR/STTR
RFA-CA-07-043	2007	1/4/2007	9/29/2007	IMAT	SBIR/STTR
RFA-CA-07-044	2007	1/4/2007	9/29/2007	IMAT	SBIR/STTR
RFA-CA-08-006	2008	1/9/2008	9/25/2008	IMAT	R21/R33
RFA-CA-08-007	2008	1/9/2008	9/25/2008	EMAT	R21/R33
RFA-CA-08-008	2008	1/9/2008	9/25/2008	EMAT	R21/R33
RFA-CA-08-009	2008	1/9/2008	9/25/2008	BIOSP	R21/R33
RFA-CA-08-010	2008	1/9/2008	9/25/2008	BIOSP	R21/R33
RFA-CA-08-011	2008	1/9/2008	9/25/2008	IMAT	SBIR/STTR
RFA-CA-08-012	2008	1/9/2008	9/25/2008	IMAT	SBIR/STTR
RFA-CA-08-013	2008	1/9/2008	9/25/2008	IMAT	SBIR/STTR
RFA-CA-08-014	2008	1/9/2008	9/25/2008	IMAT	SBIR/STTR
RFA-CA-09-004	2009	12/15/2008	10/1/2009	BIOSP	R21/R33
RFA-CA-09-005	2009	12/15/2008	10/1/2009	BIOSP	R21/R33
RFA-CA-09-006	2009	12/15/2008	10/1/2009	EMAT	R21/R33
RFA-CA-09-007	2009	12/15/2008	10/1/2009	EMAT	R21/R33
RFA-CA-09-008	2009	12/15/2008	10/1/2009	IMAT	R21/R33

FOA Number	FY Released	Posted Date	Expiration Date	Thematic Area	Funding Mechanism
RFA-CA-10-001	2010	10/6/2009	10/1/2010	BIOSP	R21/R33
RFA-CA-10-002	2010	10/26/2009	10/1/2010	BIOSP	R21/R33
RFA-CA-10-003	2010	10/26/2009	10/1/2010	EMAT	R21/R33
RFA-CA-10-004	2010	10/26/2009	10/1/2010	EMAT	R21/R33
RFA-CA-10-005	2010	10/26/2009	10/1/2010	IMAT	R21/R33
RFA-CA-10-013	2010	9/14/2010	2/9/2011	EMAT	SBIR/STTR
RFA-CA-12-002	2012	12/21/2011	9/19/2012	IMAT	R21/R33
RFA-CA-12-003	2012	12/21/2011	9/19/2012	EMAT	R21/R33
RFA-CA-12-004	2012	12/21/2011	9/19/2012	BIOSP	R21/R33
RFA-CA-12-005	2012	12/21/2011	9/19/2012	BIOSP	R21/R33
RFA-CA-13-001	2013	11/9/2012	9/21/2013	IMAT	R21/R33
RFA-CA-13-002	2013	11/9/2012	9/21/2013	EMAT	R21/R33
RFA-CA-13-003	2013	11/9/2012	9/21/2013	BIOSP	R21/R33
RFA-CA-13-004	2013	11/9/2012	9/21/2013	BIOSP	R21/R33
PAR-13-327	2013	8/3/2013	5/28/2016	EMAT	SBIR/STTR

Purpose

As described on the IMAT website (NCI, 2015a) the program:

> *…was established to support the development, technical maturation, and dissemination of novel and potentially transformative next-generation technologies through an approach of balanced but targeted innovation. In support of its mission, the IMAT program utilizes a variety of investigator-initiated research project grant mechanisms while retaining a strong commitment to diversity and to the training of scientists and clinicians in cross-cutting, research-enabling disciplines.*

The IMAT program supports:

> *…highly innovative technologies for the molecular and cellular analysis of cancers and their host environment in support of basic, clinical, and epidemiological research and clinical care. Supported projects include the development of more effective instrumentation, platforms, techniques, devices, and analytical tools that represent a substantial improvement over current state-of-the-art.*

Mechanisms of Support

The current iteration of the IMAT program utilizes the R21 (exploratory/pilot phase; RFA-CA-16-001 and RFA-CA-16-003) and R33 (developmental phase; RFA-CA-16-002 and RFA-CA-16-004) mechanisms of support.

- The **R21 Exploratory/Development Research Grant Award** is designed to encourage exploratory/developmental research by supporting the early phases of development. NCI has expanded the standard review criteria to include the development of quantitative milestones that are used to assess the feasibility of the project.
- The **R33 Exploratory/Development Research Grant Phase II Award** is designed to provide a second phase of support for exploratory/development research activities initiated under the R21 mechanism. The funding of R33 grants is predicated on the establishment of proof of principle

through prior research (e.g., R21). R33 projects are expected to generate sufficient data to validate the technology in a biologically relevant setting.

Past IMAT projects have also been supported by a combined R21/R33 mechanism, as well as the SBIR/STTR mechanisms (R41/R42 and R43/R44).

- **The Small Business Innovation Research (SBIR) Grant Award** program is designed to engage small businesses in Federal Research/R&D in order to commercialize technology. This funding mechanism allows small businesses to develop technological potential in the private sector (NIH, 2015c).
- **The Small Business Technology Transfer (STTR) Grant Award** program is designed to expand opportunities for the public and private sectors to become partners in technological innovation. One goal of this mechanism is to foster the connection between basic science and commercialization by requiring a small business to partner with a nonprofit research institution (NIH, 2015c).

Through IMAT, the SBIR/STTR mechanisms provided support to small businesses that were developing highly innovative, emerging molecular/cellular analytical technologies that had the potential to detect and/or characterize cancer (NCI, 2015d). It is expected that the technologies will have a significant likelihood for overcoming persistent challenges or opening new fields for cancer research or care (NCI, 2015d).

IMAT Thematic Areas

The current issuance of the IMAT program consists of four separate FOAs that cover the following three thematic areas (as referred to in the main body of the report). The current issuance does not include the SBIR/STTR mechanism.

1. **IMAT-themed**: Innovative Molecular Analysis Technology Development for Cancer Research (RFA-CA-16-001, using the R21 funding mechanism), which is intended to support research projects that are centered on the inception and preliminary development of highly innovative molecular analysis technologies with potentially high impact on cancer research;
2. **EMAT-themed**: Emerging Molecular Analysis Technology Development for Cancer Research (RFA-CA-16-002, using the R33 funding mechanism), designed to support further development (beyond the initial phase) of emerging molecular analysis technologies that have the potential to be transformative when used for cancer research and/or in cancer-relevant clinical care; and
3. **BIOSP-themed**: Innovative and Applied Emerging Technologies in Biospecimen Science, which is centered on the development and validation of novel technologies to improve or assess the quality of cancer-relevant biospecimens for research or clinical care. Specifically, this award is aimed to support research on tools to improve the isolation and/or preservation of proteins, DNA, RNA, and other small molecules from biospecimens or otherwise assess their biological integrity. The emphasis is on issues related to pre-analytical variations in the collection, processing, handling, and preservation of cancer-relevant biospecimens or their derivatives to improve their quality and utility for cancer research or patient clinical care.
    a. RFA-CA-16-003, using the R21 funding mechanism: Supports an early-stage feasibility study (inception through preliminary development) to demonstrate core functional capabilities of the proposed technology.
    b. RFA-CA-16-004, using the R33 funding mechanism: Assumes completion of the initial phase of development and supports the advanced development and robust validation of the technology.

Program Stakeholders

Stakeholders of the IMAT program were identified and classified into three major categories using steps from the Centers for Disease Control and Prevention Introduction to Program Evaluation Manual (2012):

- Those involved with **program operations**:
  - **Funding Agency**: NCI and its senior staff; IMAT staff members
- Those **served** or **affected** by the program:
  - **Program Participants**: PD/PIs; Research Team; and Institution
  - **Other Federal Stakeholders**: Federal staff located within other NCI divisions; across the NIH (e.g. NIGMS, National Institute of Biomedical Imaging and Bioengineering (NIBIB); NSF; Office of Integrative Activities; and the National Institute of Standards and Technology (NIST) Advanced Technology Program (ATP)
  - **External Program Beneficiaries**: Other researchers and the scientific community at large, especially the biotechnology industry; technology End Users; clinicians; patients; and advocacy communities
- Those who are **intended users** of the evaluation findings:
  - IMAT staff members; NCI senior staff; NIH leadership and other Federal Government stakeholders, including the Evaluation Advisory Committee described in the introduction section of this report.

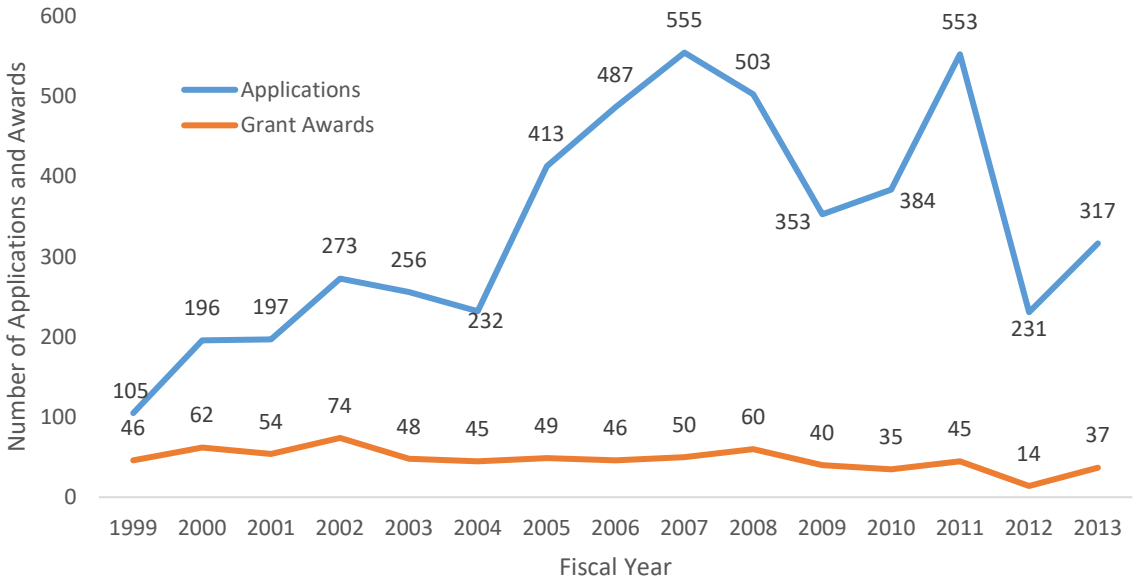
IMAT Applications and Awards

The IMAT program has released a total of 77 FOAs since its inception in 1998. The majority (n=53) utilized an R21/R33 funding mechanism. The remaining 24 FOAs utilized an SBIR/STTR mechanism.

Since 2005, the IMAT program has typically released between two and nine individual FOAs in a fiscal year, with the exceptions being FY2007 when a total of 29 FOAs were released and FY2011 when no FOAs were released. Appendix E shows a breakdown of FOAs released by the IMAT program by fiscal year categorized by the funding mechanism utilized.

In response to the 77 FOAs, the IMAT program received a total of 5,055 application submissions; of these, 705 were awarded (Figure 54). The application and award dates for a given FOA can be separated by up to three years from the release date of the FOA based on the expiration date of the FOA.

Figure 54. IMAT Applications and Awards by Fiscal Year



Funding Mechanism

Of 5,055 applications submitted to the IMAT program, the majority of applications (4,125), were submitted to an R21/R33 funding opportunity, with 540 receiving awards. The remaining 930 applications were submitted to an FOA for an SBIR/STTR mechanism; 165 of these applications were awarded grants. The breakdown of applications submitted to R21/R33 FOAs, and the resulting awards by fiscal year is presented in Figure 55. The distribution of SBIR/STTR applications and awards is presented in Figure 56.

Figure 55. IMAT Applications and Awards Resulting from R21/R33 Funding Opportunities

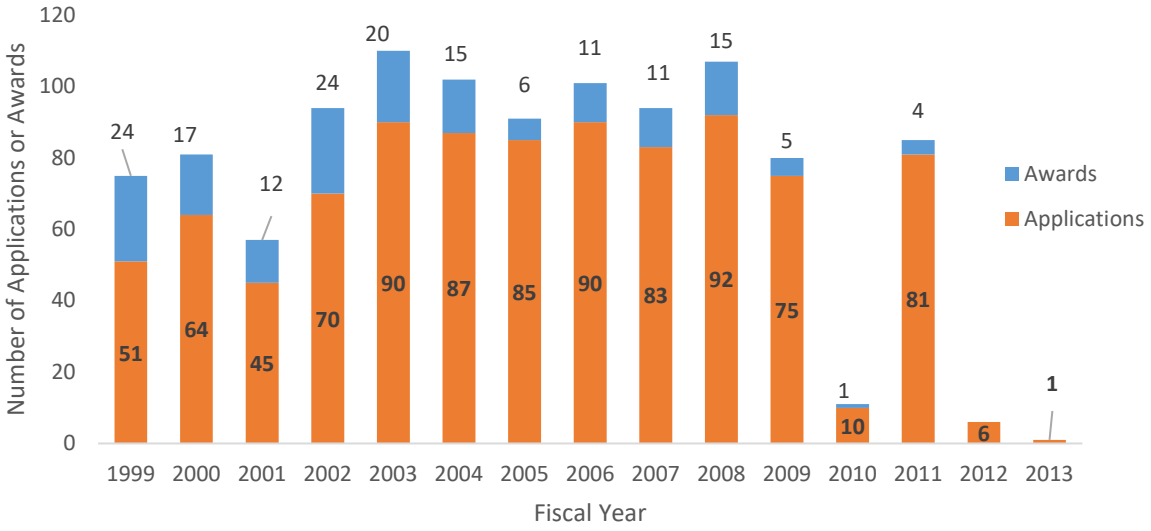
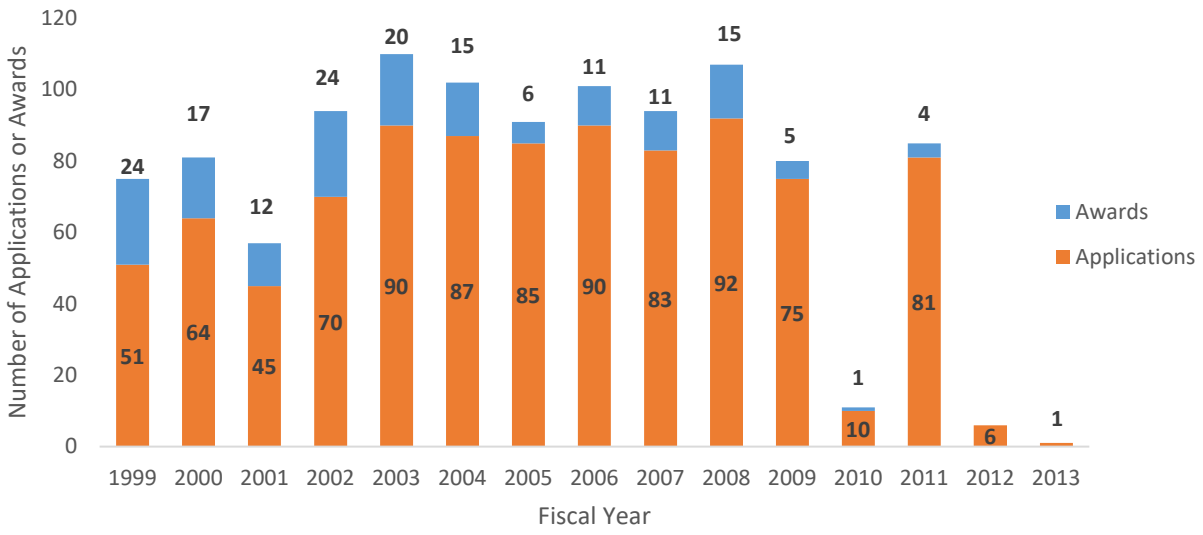


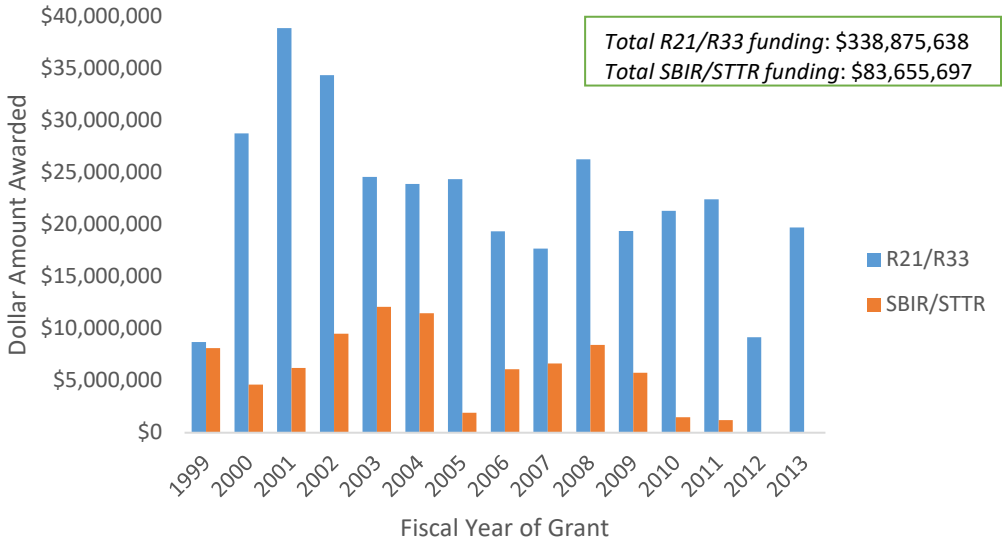
Figure 56. IMAT Applications and Awards Resulting from SBIR/STTR Funding Opportunities



Grant Funds

According to archival data, more than $422,531,000 has been awarded to IMAT projects during FYs 1999 to 2013. Figure 57 depicts the amounts awarded annually from FY1999 through FY2013. No SBIR/STTR grants were awarded in 2012 or 2013.

Figure 57. Dollar Amount Awarded by Fiscal Year and Funding Mechanism

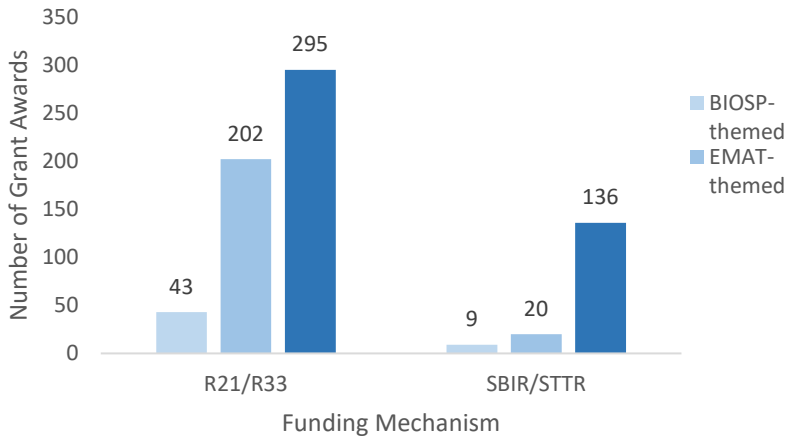


Grant Awards by Thematic Area

Each year when there was more than one active FOA, the distribution of awards among thematic areas was determined by the quality of the applications and NCI priorities. The majority of grant awards, for all funding mechanisms, were within the IMAT thematic area (Figure 58). Within the R21/R33 awards,

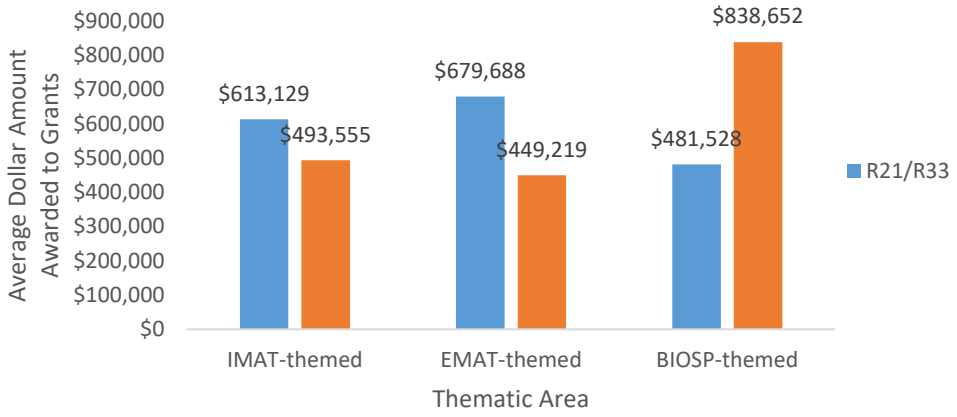
54.6% (n=295) were IMAT-themed, while 37.4% (n=202) were Emerging Molecular Analysis Technologies (EMAT)-themed, and 7.9% (n=43) were biospecimen (BIOSP)-themed. Among SBIR/STTR awards, 82% (n=136) were IMAT-themed, 12.1% (n=20) EMAT-themed, and 5.4% (n=9) BIOSP-themed.

Figure 58. IMAT Grant Awards by Thematic Area



The figure below depicts average dollar amounts awarded by thematic area and funding mechanism. IMAT-themed and EMAT-themed awards were comparable to each other. For BIOSP-themed awards, the average amount for SBIR/STTR awards was higher than any of the other categories.

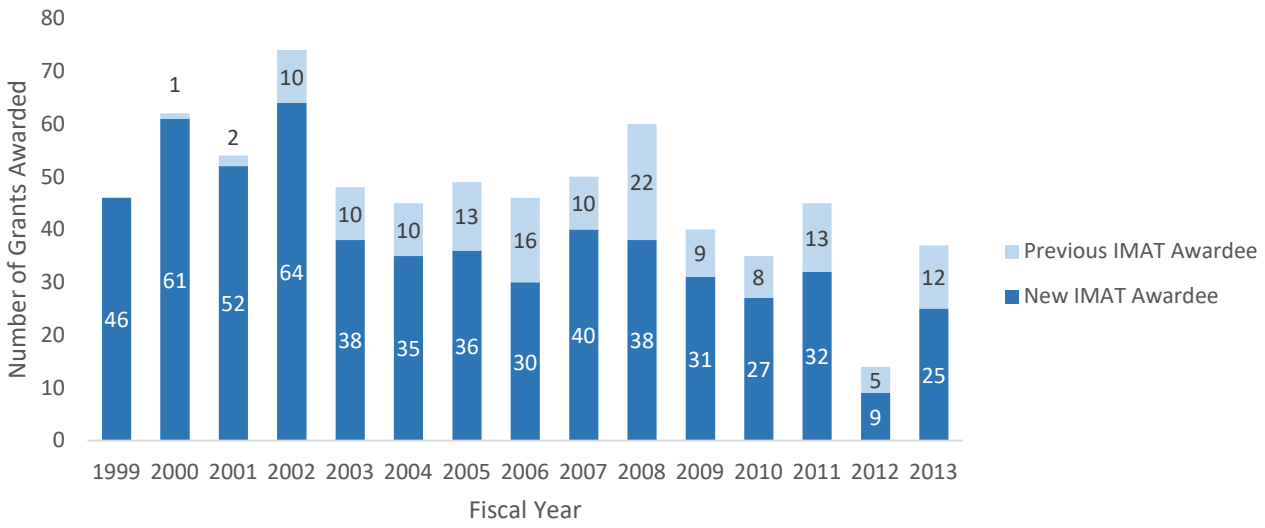
Figure 59. Average Dollar Amount Awarded by Thematic Area and Funding Mechanism



New and Previous IMAT Principal Investigators

IMAT's focus is on the early stages of technology development; thus, it is common for investigators to apply to the program for follow-on funding to further develop the technology or methodology from their initial award, or to begin development on new technologies or methodologies. According to the survey, of all PD/PIs who applied for an IMAT grant, 51.3% had submitted previous IMAT applications (both successful and unsuccessful). Of all awarded IMAT grants, 20% were awarded to PD/PIs who had previously received one or more IMAT awards. Figure 60 depicts the grants awarded to these two groups (previous IMAT PD/PIs and new IMAT PD/PIs) by year.

Figure 60. IMAT Grants Awarded to PD/PIs, by Previous Award Status



Slightly under 75% of PD/PIs receiving IMAT funds for the first time were funded through the R21/R33 funding mechanism, while the remaining 25.5% of new PD/PIs received IMAT funding under the SBIR/STTR mechanisms. Among PD/PIs who had previously received IMAT awards, 85.1% were funded under R21/R33 and 14.9% were funded under SBIR/STTR.

History of IMAT Evaluation Activities

NCI has previously commissioned four evaluative contracts for the IMAT program:

- Feasibility Study for Outcome Evaluation of IMAT Program, Macro International (2007)
- Outcome Evaluation Report, SAIC Corporation (2008)
- Evaluation Update Report, Science & Technology Policy Institute (2010)
- Targeted Evaluation Activities, Thomson Reuters – Custom Analytics Group (2013)

A summary of these prior evaluation activities is presented in Appendix D.

Appendix C – Case Study Evaluations of IMAT Grantees

As a component of regular program management, NCI regularly evaluates the most recently completed awards in the IMAT portfolio on an ongoing basis. Ripple Effect supported NCI staff with a recent assessment of the outcomes from IMAT grants closing in FY2015 (for which applications were submitted in FY2012 and FY2013). The assessment focused on the scientific contributions of the grant-funded technologies. The following 18 case studies provide evidence of the program's successes in a format that is acknowledged[16] for its usefulness in conveying dissemination and commercialization-related metrics for assessing technology development programs.

Table 30. IMAT Grantees Included in Case Studies Evaluation

Project	PI Name(s)	Duration of Support for Case Study
CA160011	Nolling, Jork	1 Year
CA160060	Wang, Zhenghe	2 Years
CA173092	Davalos, Rafael Vidal (contact); Cramer, Scott	2 Years
CA173245	Caron, Marc	2 Years
CA157298	Aksan, Alptekin	3 Years
CA160132	Lam, Kit	3 Years
CA173124	Dayton, Paul (contact); Janzen, William Perry	3 Years
CA173164	Steinman, Richard	3 Years
CA173205	Tao, Nongjian	3 Years
CA173303	Cartegni, Luca	3 Years
CA173347	Grzybowski, Bartosz Andrezej	3 Years
CA173359	Liotta, Lance Allen	3 Years
CA173382	Zu, Youli	3 Years
CA173390	Wang, Tza-Huei	3 Years
CA174616	Hsiao, Shih-Chia (contact); Francis, Matthew	3 Years
CA177447	Jeffrey, Stefanie	3 Years
CA177535	Liotta, Lance Allen	3 Years
CA182333	Tavana, Hossein (contact); Luker, Gary	3 Years

[16] https://www.ida.org/idamedia/Corporate/Files/Publications/STPIPubs/2016/d-5712.ashx

PI: NOLLING, JORK N.

Institution: **PRIMERADX, INC.**

Project #: **R33CA160011**

Title: **A Highly Multiplexed PCR Platform for Gene Expression Profiling from FFPE Tissue**

Overview. The goal of this project was to further develop and validate the ICEPlex platform, targeting the ability of the platform to successfully differentiate large B-cell lymphoma (DLBCL) into subgroups (activated B-cell [ABC] and germinal center-derived B-cell [GCB] subgroups) as a means of fully establishing the capabilities of the instrument. This platform would provide a robust, low-cost, multiplexed, automated assay for identifying genomic signatures from FFPE samples for clinical diagnostics.

Development steps included sample preparation protocols that allowed use of formalin-fixed, paraffin-embedded (FFPE) tissue as the RNA source. The assay was used to screen a panel of genes identified in the literature as being useful for this classification (plus control genes as internal standards). The assay and instrument were compared to a custom reference microarray (Affymetrix) used to classify the tumor specimens for both techniques.

Project Aims. The PI *successfully accomplished* the aims of this single-year award. The PI developed and validated both a technology that was purchased by Qiagen (now marketed as ModaPlex), and also a laboratory test currently being used at the Cleveland Clinic for the subclassification of patients as described above.[17]

Publications and Citations. Findings that led to this clinical capability have been documented in a single publication.

Licenses and Patents.[18] The Cleveland Clinic holds the proprietary claim on the key data processing algorithm that was developed, but not a patent or license for the technology; the technology had already received patent protection.

Clinical Trials. Straight to clinical application.

Collaborations/Partnerships. The PI expressed an interest in contributing the NCI RAS project.

Follow-up Applications/Awards. None reported; the technology continues to be used.

---

[17] Cleveland Clinic Laboratories. (2014). Diffuse large b-cell lymphoma molecular subtyping (Technical Brief 201408.015). Cleveland, OH: Author. http://clevelandcliniclabs.com/assets/pdfs/technical-briefs/diffuse-90198.pdf

[18] Patents cited may be for associated technology developed using funding from a previous award.

PI: WANG, ZHENGHE

Institution: **CASE WESTERN RESERVE UNIVERSITY**

Project #: **R21CA160060**

Title: **Developing Novel Technology for Mapping Dynamic Oncoprotein Interaction Networks**

Overview. The goal of this project was to combine two existing technologies, endogenous epitope tagging and affinity purification mass spectrometry (AP-MS), into a platform for mapping dynamic oncoprotein interaction networks. The approach involved tagging and profiling oncogenes via recombinant adeno-associated virus (rAAV) strategy to identify differential wild-type and mutant oncoprotein interaction networks and to characterize dynamic protein interaction networks across subcellular compartments (e.g., nuclear vs. cytoplasm).

Project Aims. The PI *successfully achieved* the two project aims. While the approach had been attempted by a number of investigators at the time, this team was the first to succeed in making it work. One challenge worth noting is the emergence of CRISPR/Cas9 gene editing techniques and the clear advantages for achieving double or higher the targeting efficiency of the rAAV approach. This led the team to adapt the method along the way; now they use CRISPR as the primary tagging approach.

Publications and Citations. Accomplishments have been highlighted in ten publications, with at least two more under development.

Licenses and Patents.[19] A patent application is under consideration by the USPTO. The technology has been licensed to a British company to make commercially available reagent kits for new protein-protein interaction studies. The PI reports having made reagents available to a number of investigators.

Clinical Trials. None reported.

Collaborations/Partnerships. The PI is working with another IMAT PI and also has indirect collaborations with a consultant for SUNY on a stable peptide optimization technology.

Follow-up Applications/Awards. The PI submitted an application for an R01 grant but did not receive an award.

[19] Patents cited may be for associated technology developed using funding from a previous award.

PI: DAVALOS, RAFAEL VIDAL; CRAMER, SCOTT D.

Institution: **VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY**

Project #: **R21CA173092**

Title: **Isolation of Tumor Initiating Cells (TICs) using Contactless Dielectrophoresis**

Overview. The goal of this project was to develop a novel platform for the rapid separation of prostate tumor-initiating cells (TIC) from fluid samples. The approach was a variation on dielectrophoresis (DEP)-based separation called contactless dielectrophoresis (cDEP), and involved a novel design that separated the electric field-generating electrodes from the sample space. While DEP is a proven tool for isolating circulating tumor cells from blood (most notably by the ApoCell platform from Apostream), it remains technically difficult and expensive to use, with electrode deterioration being a persistent problem. Furthermore, characterizing TICs has high significance for all areas of cancer research; a novel high-throughput system for sorting these critical cells, many of which cannot be identified by surface markers, is a significant unmet need.

Project Aims. The PIs have been *partially successful* in meeting two proposed project aims. They have achieved performance levels similar to Apostream, but with greater sensitivity. One incidental finding is that their cDEP approach has been capable of distinguishing changes in phenotypic processes due to drug exposure. If current efforts to distinguish more aggressive subpopulations are successful, a new clinical screening capability may result for guiding a personalized treatment strategy based on the patient's liquid biopsy (i.e., a precision-medicine strategy). Processing time is still a significant issue for the cDEP platform, however, and the PI recognizes this must improve.

Publications and Citations. The PIs have published two publications with two more in process.

Licenses and Patents.[20] The PI has submitted three patent applications for this technology, with one having received an award. A new small business (PhenoChip) has licensed the technology and will pursue various commercialization opportunities.

Clinical Trials. None reported.

Collaborations/Partnerships. A new collaboration has formed between the PI and a clinician interested in using the cDEP technology to overcome persistent hurdles in his research, which uses fluorescence-activated cell sorting (FACS) to isolate TICs for leukemia from patient samples.

Follow-up Applications/Awards. The PI unsuccessfully applied for R33 support to continue development through the IMAT program, but has taken a year to generate more ideas about how to vary the handling parameters to improve performance, and to identify problems better suited for the application of this unique instrument.

[20] Patents cited may be for associated technology developed using funding from a previous award.

PI: CARON, MARC G.

Institution: **DUKE UNIVERSITY**

Project #: **R21CA173245**

Title: **A Cancer Rainbow Mouse for the Simultaneous Assessment of Multiple Oncogenes**

Overview. The goal of this project was to develop Crainbow Mouse technology, which would allow mosaic expression of multiple oncogenes in a single mouse. The technology is expected to improve the access, reliability, cost, and amount of time required for rapid analysis of selected oncogenes. The approach involved the development of complex genetic vectors with cassettes that bicistronically expressed unique compartmentalized reporters and epitope-tagged oncogenes to achieve Cre-induced expression of the genes targeted. The technology is intended to facilitate concomitant lineage-tracing studies of the cell clones and tumors that arise from each oncogene as demarcated by oncogene-specific, spectrally-resolvable, and compartmentalized fluorescent reporters.

Project Aims. After overcoming hurdles in achieving expression of the targeted fluorescing gene products, the PI's team *ultimately achieved* the three project aims and met each of the quantitative milestones. The team was not only able to achieve intratumoral expression of at least four different oncogenes within the tumor (with assertions from the PI that they can achieve up to 10), but also in reducing the time necessary for establishing appropriate and mature mouse colonies from >16 months down to 4-6 months.

Publications and Citations. The PIs report that three manuscripts are in various stages of development and review.

Licenses and Patents. The PI intends to pursue patent protection once the methodology is established.

Clinical Trials. None reported.

Collaborations/Partnerships. None reported.

Follow-up Applications/Awards. The PIs successfully applied for follow-up funding with a recent R33 award from the IMAT program. Among the current development goals are to optimize efficiency of genetic targeting and expression by incorporating gene-editing tools (such as CRISPR), and to validate the Crainbow Mouse technology for a broad variety of applications including basic etiology studies and drug sensitivity and resistance testing.

PI: AKSAN, ALPTEKIN

Institution: **UNIVERSITY OF MINNESOTA TWIN CITIES**

Project #: **R21CA157298**

Title: **Development of Room-Temperature Storage Technique for Plasma/Serum Biospecimens**

Overview. The goal of the project was to develop a novel approach to preserve and store serum biospecimens at room temperature via isothermal vitrification of serum samples. Isothermal vitrification is the process by which liquids doped with sugars are desiccated to a "glass" (a very viscous fluid), where biochemical reactions are halted, degradation of the specimen is stopped, and macromolecules are stabilized in their native states.

The project involved developing and optimizing mixtures of lyoprotectant chemicals to achieve rapid vitrification, then testing the merits of both standard filter paper and an electrospun fiber "sponge" for streamlining vitrification, retention, and storage, and for subsequent elution for molecular analysis. The new approach would prevent damage to the serum biospecimens, which in turn would improve the quality of the specimen and reduce required resources.

Project Aims. The PI has *met* one of the four project aims, which has resulted in the identification of a substantial number of lyoprotectant mixtures that have achieved vitrification in less than 30 minutes (under vacuum). The PI was unsuccessful in recovering more than 80% of proteins from the controlled serum mixture using standard filter paper, but has had a great deal of success in recovering 100% of up to six proteins from the controlled mixture from the electrospun matrix. The PI has reported significant difficulty in developing an effective matrix, which he calls simply "sponge," and continues to struggle with scaling up the fabrication yield. The remaining work involves scaling up the number of proteins recoverable from the methodology, more-rigorous testing of longer term storage periods, and improving the fabrication yield for creating more sponge.

Publications and Citations. The PI has two publications in print and has reported another in development.

Licenses and Patents.[21] The PI reports that a patent application is in the final preparation stages.

Clinical Trials. None reported.

Collaborations/Partnerships. None reported.

Follow-up Applications/Awards. The PI intends to seek R33 support to resolve the indicated hurdles.

[21] Patents cited may be for associated technology developed using funding from a previous award.

PI: LAM, KIT S.

Institution: **UNIVERSITY OF CALIFORNIA DAVIS**

Project #: **R33CA160132**

Title: **Discovery of Death Ligands against Cancers**

Overview. The PI proposed to build upon a prior innovation known as one-bead-one-compound (OBOC) in order to develop novel one-bead-two-compound (OB2C) material libraries to rapidly screen for cell-surface agonists and antagonists. The approach offered substantial advantages over existing combinatorial chemical-screening studies, including the elimination of the need to culture cells in microtiter plate wells, and the reduction of the time and complexity in screening much larger libraries.

Project Aims. The PI has *accomplished* most of the three project aims, having successfully developed ten novel libraries and applied them to discover five new therapeutic targets for ovarian cancer.

Publications and Citations. The progress has been documented in two publications; further publication is being held until a patent currently under preparation can be submitted.

Licenses and Patents.[22] A patent is currently in preparation.

Clinical Trials. None reported.

Collaborations/Partnerships. None reported.

Follow-up Applications/Awards. Developing OB2C has led to a new R21 award from NIH, and the PI has submitted a U01 and separate R01, both currently under review, to explore the efficacy of OB2C with *in vivo* studies for both prostate and ovarian cancer. The PI has also suggested significant interest in exploring the commercial potential of these libraries through an existing small business entity he currently presides over.

[22] Patents cited may be for associated technology developed using funding from a previous award.

PI: DAYTON, PAUL A; JANZEN, WILLIAM PERRY

Institution: **UNIVERSITY OF NORTH CAROLINA at CHAPEL HILL**

Project #: **R21CA173124**

Title: **Cavitation Enhancement of Biospecimen Processing for Improved DNA Fragmentation**

Overview. This project involves a very simple yet potentially powerful idea to create an efficient method for rapid and random fragmentation of DNA into smaller but uniformly sized fragments using microbubbles as cavitation reagents under ultrasonic bath stimulation. The approach would yield a DNA sample preparation technique for purified genomic DNA or formaldehyde crosslinked samples appropriate for next-generation sequencing (NGS) and chromatin immunoprecipitation (ChIP). Successful development of this method would result in a faster and more cost-effective approach compared to alternatives, and it would also eliminate agarose-gel extraction or bead-based cleanup and size-selection steps, thereby minimizing sample handling time and generally reducing DNA damage, which are the critical bottlenecks in the pre-analytical processing of DNA samples.

Project Aims. The PIs have *accomplished* the first two aims of the project, meeting key milestones that have prompted enthusiasm among collaborators for the emerging technology (especially regarding 250 times the cost reduction).

Publications and Citations. The PIs have submitted one publication.

Licenses and Patents.[23] A patent has been filed, and the PIs report that several companies have expressed an interest in licensing the technology for commercialization.

Clinical Trials. None reported.

Collaborations/Partnerships. Collaborations with two colleagues, one at the University of North Carolina and the other at Mount Sinai, have led to the method being used as a cost savings measure for one genomics investigator, and further testing of the method using nanodroplets with both mitochondrial DNA and formaldehyde crosslinked chromatin fragmentation.

Follow-up Applications/Awards. The PIs are interested in both IMAT R33 and IMAT SBIR support to continue development and validation of the technique.

[23] Patents cited may be for associated technology developed using funding from a previous award.

PI: STEINMAN, RICHARD A.

Institution: **UNIVERSITY OF PITTSBURGH AT PITTSBURGH**

Project #: **R21CA173164**

Title: **Exosomal Recombinase-A Tool to Dissect Metastasis and the Cancer Microenvironment**

Overview. The goal of this project was to engineer cancer or host cells to irreversibly mark nearby cells by means of novel exosomal Cre-recombinase constructs, leveraging evidence that exosomal Cre-bearing cancer cells trigger bystander cell recombination both *in vitro* and in a specific (e.g., hypoxic) niche *in vivo.* The technology would allow for controlled cell-to-cell transmission of Cre-recombinase via designed fusion genes that combine Cre, a red fluorescent marker, and portions of exosomal proteins. The effect would be a signal-amplifying tool that labels each cell that was touched by a cancer cell actively moving through tissue. The project would primarily be developed in cell culture, then *in vivo* in an appropriate mouse model. The end result of isolating a trajectory is the capacity to then compare the behaviors of the cells that contacted the cancer to those of similar cells that did not contact the cancer to further understanding of metastasizing cancer. Currently a tracking tool does not exist; this technology could potentially open a new analytical profiling of cancer biology.

Project Aims. The PI *has met one of the two* project aims. He has been successful in demonstrating this approach in cell cultures (Aim 1), but has continued to struggle making progress in mouse models (Aim 2). The principle hurdle cited by the PI is substantial contamination issues at the veterinary facility repeatedly preventing adequate access to animals necessary to perform the *in vivo* experiments. They have also discovered low-level toxicity with the cells from the Cre-recombinase constructs and low success in bypassing interference/clearance by the lysosome to achieve successful delivery to the nucleus.

Publications and Citations. None reported.

Licenses and Patents. None reported.

Clinical Trials. None reported.

Collaborations/Partnerships. None reported.

Follow-up Applications/Awards. The PI has requested a no-cost extension to resolve current hurdles and continue pursuing the *in vivo* studies.

PI: TAO, NONGJIAN

Institution: **ARIZONA STATE UNIVERSITY-TEMPE CAMPUS**

Project #: **R21CA173205**

Title: **Charge Sensitive Optical Detection for High Throughput Study of Small Molecules**

Overview. The goal of this project was to develop a label-free method of detecting small molecule binding and post-translational modification events using a novel optically-tracked, oscillating, functionalized optical-fiber probe that can detect changes in surface charge density. The fiber oscillates in the sample, and the fiber is functionalized by adsorbing specific binding agents (such as antibody fragments or aptamers) to the surface of the fiber, which can then detect the changes in optical fiber surface charge density upon binding to targets in the solution.

The sensor mechanism is based on Charge Sensitive Optical Detection (CSOD), used to monitor charge change rather than mass change due to binding events, which is better suited for monitoring small-molecule interactions such as phosphorylation and other post-translational modifications (PTMs). This highly sensitive biosensor platform may be transferable to, and useful for, other research questions and screening applications beyond PTMs. The project involves developing a tool in 96-well plate array format to enable multiplexing, and to validate the technology by quantifying phosphorylation in the BCR-ABL1 kinase system.

Project Aims. The PI has completed two of the three project's aims and expects to complete the third by project close.

Publications and Citations. The PI has published one article with another in the review process.

Licenses and Patents.[24] A patent application has been submitted and licensing with Biosensing instruments is underway.

Clinical Trials. None reported.

Collaborations/Partnerships. The PI has established two new collaborations (Genentech and Biosensing Instrument Inc.) and continued to work with a third pre-existing collaborator (Amgen); all three are interested users or potential producers.

Follow-up Applications/Awards. The PI intends to submit an application for further support through an IMAT R33 and is discussing a potential R01 application with two collaborators.

[24] Patents cited may be for associated technology developed using funding from a previous award.

PI: CARTEGNI, LUCA

Institution: **SLOAN-KETTERING INSTITUTE FOR CANCER RESEARCH**

Project #: **R21CA173303**

Title: **Controlled Premature Termination of Translation to Generate Designated Truncated Variants**

Overview. The goal of this project was to develop an approach for creating specific truncated mutant proteins, by applying a new antisense technology, termed self-wrapping anti-sense translation terminator (SWATT). The technology induces the expression of truncated variants of oncogenic proteins by introducing a physical "road-block" into the path of ribosomes during translation at specific, pre-determined points, forcing them to interrupt protein synthesis and resulting in premature translational termination. Successful development might yield mutant proteins with a dominant-negative, anti-oncogenic effect, and thereby a novel class of therapeutic agents.

Project Aims. Substantial delays were incurred on this project as a result of the PI moving from one institution to another, with a much longer than expected period required for setting up the new laboratory in which to accomplish the proposed aims. While significant progress has been made in creating an initial set of SWATT constructs with the desired translation interruption activity, the PI has yet to complete all element of the first (of two) aims for establishing reliable interruption of translation *in vitro*.

Publications and Citations. The PI has one publication.

Licenses and Patents.[25] The PI has submitted two patent applications.

Clinical Trials. None reported.

Collaborations/Partnerships. None reported.

Follow-up Applications/Awards. None reported.

[25] Patents and applications cited may be for associated technology developed using funding from a previous award.

PI: GRZYBOWSKI, BARTOSZ ANDRZEJ

Institution: **NORTHWESTERN UNIVERSITY**

Project #: **R21CA173347**

Title: **Microsystems for Targeting Lévy Walks in Metastatic Cancer Cells**

Overview. The goal of this project was to develop a novel technological platform for quantitative analysis of Lévy walk motility of metastatic cancer cells. While non-metastatic cells execute simple, diffusive random walks, their metastatic variants move super-diffusively and also perform Lévy walks in which step-times are drawn from probability distributions with heavy power-law tails. It has been proposed that disruption of Lévy walking could inhibit metastatic potential.

The proposed technology was a high-throughput cell migration assay with linear 1D microtracks integrated in a 96-well format along with appropriate software modules to automate the microscopy and image acquisition/analysis. A set of 50 genes known or predicted to be involved in cell migration were targeted by short interfering RNA to assess Lévy walk behavior across large populations of cells using the fully automated 1D microtrack assay.

Project Aims. The first of the three specific aims for this project to fabricate the microtracks and automate analysis of motile cells was *successfully completed*, and *substantial progress* was made on the third aim of implementing siRNA screens to monitor the contributions of individual regulators to cell motility. The PI has yet to report success on the second aim involving fabrication of the 96-well version of the microtracks system.

Publications and Citations. One publication.

Licenses and Patents. None reported.

Clinical Trials. None reported.

Collaborations/Partnerships. None reported.

Follow-up Applications/Awards. The PI has been awarded a follow-up R21 award to continue research focused on aberrant motility behavior of metastatic tumor cells using the microtracks platform.

PI: LIOTTA, LANCE ALLEN

Institution: **GEORGE MASON UNIVERSITY**

Project #: **R33CA173359**

Title: **Nanotrap Technology for One Step Preservation and Amplification of Cancer Biomarkers**

Overview. The project goal was to further develop and analytically validate a technology called Nanotrap©. The technology was developed through both R21 and R33 support to capture, enrich and concentrate low abundance proteins in bodily fluids, including blood, urine and sweat. The technology consists of porous, core-shell hydrogel nanoparticles that contain a variety of small molecule affinity reagents that act as bait to selectively bind specific low abundance proteins.

Project Aims. The three specific project aims included using Nanotraps specific for up to 24 low-abundance proteins (1 ng/mL) and quantifying their abundance by multiple reaction monitoring mass spectrometry (MRM-MS) in human sera and plasma to validate the analytical performance of the nanoparticles as clinical grade immunoassays. Technical advancements included reduction of the required sample volume, improving the lower limit of detection, and demonstrating application with human sweat.

While only the early aims of this project have been completed, and much work remains from the R33 proposal, the PI has been highly successful in achieving up to 10,000-fold improvement on the lower limit of detection and precision for mass spectrometry-based biomarker detection in both discovery and screening applications.

Publications and Citations. The PI has 15 publications.

Licenses and Patents.[26] The PI has successfully patented (awarded 3 US and 2 non-US patents, with an additional 14 under consideration), commercialized (non-exclusive licensing by Ceres Nanosciences and Thermo Fisher, and further marketing by Shimadzu), and obtained CAP/CLIA certification (CAP#7223012) for Nanotrap analyte harvesting and concentration method at the George Mason clinical laboratory.

Clinical Trials. A clinical trial using Nanotrap as a diagnostic technology for Lyme disease is currently underway.

Collaborations/Partnerships. Collaborators at Columbia are following up on the NSCLC biomarkers identified using Nanotrap©; other collaborators not specified, but PI indicates other researchers have used the technology to find whole, living viruses; it is also being used in salvia and for prostate cancer.

Follow-up Applications/Awards. The PI has made seven follow-up applications to NIH, with one awarded and another currently under review.

[26] Patents cited may be for associated technology developed using funding from a previous award.

PI: ZU, YOULI

Institution: **METHODIST HOSPITAL RESEARCH INSTITUTE**

Project #: **R33CA173382**

Title: **Activatable One-Drop and One-Step Assay for Circulating Tumor Ce**

Overview. The project goal was to develop a clinical assay for detecting circulating tumor cells (CTC) in a high throughput and single-step manner. The current state of CTC detection necessitates several milliliters of blood and a complex reaction that requires multiple specific antibody binding steps. The PI proposed to develop a unique aptamer probe that carries a "tumor cell-activatable" reporting system similar to FRET (the fluorophore is activated only after internalization); the system is referred to as a "One-Drop (of blood)-One-Step Assay" (ODOSA).

The aptamer probes specifically bind tumor cell surface biomarker(s) and are optically silent in the absence of target cells. Thus, the fluorophore-quencher pair has low background, but strong signal upon internalization. The application is unique in the use of an aptamer to target tumor cell surface markers that need to be internalized for activation of the fluorescence signal to detect tumor cells. This design and approach would allow clinicians to identify tumor cells in minute amounts of blood samples in an easy and efficient manner.

Project Aims. The PI has met two of the three project aims, which included optimizing the sensitivity and specificity of the aptamer probes for ODOSA technology, and developing a high-throughput platform for the ODOSA. Ultimately, they will validate the technology with the appropriate clinical specimens.

Publications and Citations. The PI has 11 publications.

Licenses and Patents.[27] A patent application has been submitted.

Clinical Trials. None reported.

Collaborations/Partnerships. The PI reports that a hospital in China is working with BrCa patient samples, and is also in collaboration with PanCan.

Follow-up Applications/Awards. The PI was awarded an STTR grant to label cells.

[27] Patent application cited may be for associated technology developed using funding from a previous award.

PI: WANG, TZA-HUEI

Institution: **JOHNS HOPKINS UNIVERSITY**

Project #: **R21CA173390**

Title: **PCR-free Multiplexed Detection of Circulating miRNA in Blood**

Overview. The goal of the project involved a collaboration between a clinical oncologist and a bioengineer to develop a novel, multiplexed method to detect circulating miRNAs in a manner that is highly sensitive without necessitating amplification, and which requires very low sample volume. The PI proposed to use cylindrical illumination confocal spectroscopy (CICS) to quantify low concentration miRNAs through single molecule counting. The investigator team performed a head-to-head comparison of their ligation-based multiplexed miRNA (Ligo-miR) detection technology against the Applied Biosystems Taqman qRT-PCR to establish the superiority of the proposed system using four esophageal cancer cell lines.

Project Aims. The PI has *met* all three project aims. The assay is PCR-free, and achieved PCR-equivalent sensitivity of 10^{-22} moles and a specificity of greater than 1000:1 for unrelated miRNA and greater than 100:1 for related miRNA. The PI was able to validate the assay with clinical samples by analyzing a panel of 20 miRNAs in 200 μL of serum in a single reaction. The results were compared to those obtained by real time quantitative PCR, which required 4 mL of serum split into 20 separate single-plex reactions. Beyond reducing the test time by nearly half and reducing sample volume requirements, the investigator team also reported a more than 3-fold cost reduction per test.

Publications and Citations. The PI has published 10 articles.

Licenses and Patents.[28] A patent application has been submitted.

Clinical Trials. None reported.

Collaborations/Partnerships. Colleagues at the PI's institution are using the Ligo-miR assay for ongoing breast cancer and lung cancer studies.

Follow-up Applications/Awards. A beta version of Circulomics should be ready soon and the PI has an R43 to work on getting a reagent kit in the right shape for cost effective dissemination. The PI is considering application for an R33, and expects to be awarded an SBIR R44 on LigoMiR.

[28] Patent application cited may be for associated technology developed using funding from a previous award.

PI: HSIAO, SHIH-CHIA; FRANCIS, MATTHEW B.

Institution: **ADHEREN, INC.**

Project #: **R33CA174616**

Title: **The Development of a Microscopy-Based Cell-Array Toxicity Assay for Quantifying CDC and ADCC Results at Single Cell Resolution**

Overview. The goal of this project was to scale up and validate the cell-array toxicity (CAT) assay, which is a platform that immobilizes whole cells on a prepared surface by DNA linkers in a grid formation, based on their DNA-based adhesion technology called *programmable cell adhesion (PCA)*. The platform allows for real-time optical tracking of antibody-dependent cellular cytotoxicity (ADCC) and complement-dependent cytotoxicity (CDC) for each cell screened. These two cytotoxicity measures are standard components of drug development; therefore, a low-cost, high-throughput method with single-cell precision represents a very useful tool for drug developers at both the academic and industrial level.

Project Aims. The PIs *successfully achieved* the two project aims of this single-year award, which involved implementing the approach on the substrate surfaces of 96-well microplates, and following up with a robust validation for high-throughput antibody therapy screening with a commercial collaborator (Eureka Therapeutics). The new platform improves yield and production cost.

Publications and Citations. Some of the progress has been captured in a single publication, and the PI reports additional manuscripts are being prepared for submission.

Licenses and Patents.[29] The enabling PCA technology is covered by a broad patent to the University System of California, and licensed to both Adheren (the PI's company) and Eureka Therapeutics.

Clinical Trials. None reported.

Collaborations/Partnerships. Adheren manages all ADCC and CDC testing on behalf of Eureka, and arrays are also commercially available through a Japanese distributor, with several units already having been sold to investigators not affiliated with the development. Among these early customers is the US National Institute of Standards and Technology (NIST).

Follow-up Applications/Awards. None reported.

[29] Patent cited may be for associated technology developed using funding from a previous award.

PI: JEFFREY, STEFANIE S.

Institution: **STANFORD UNIVERSITY**

Project #: **R21CA177447**

Title: **A Droplet-Based System for Capture, Manipulation, and Biochemical Profiling of Rare Cells**

Overview. The goal of the project was to develop a device to isolate and characterize circulating tumor cells (CTCs) from blood and disseminated tumor cells (DTCs) from bone marrow. The PI proposed applying the electrowetting-based liquid handling capabilities of the Advanced Liquid Logic platform to isolate single cells from blood (e.g., CTCs) to yield individual cells available for a variety of molecular analyses as well as culturing. The primary advantage of the proposed approach was the potential speed at which the samples could be processed, and the scalability of the design.

Project Aims. The PI has *not met* any of the project aims. Significant challenges emerged in the first year when the Advance Liquid Logic company was purchased by Illumina, and challenges in establishing a new relationship with Illumina prevented the use of that platform as the foundation for advancing the envisaged approach. The PI has identified an alternate strategy to realize the ultimate device design, and after a substantial delay is now making progress towards testing the prototype with the first experiments. It is anticipated that substantially more will be available on the potential of this technology in another year's time.

Publications and Citations. None reported.

Licenses and Patents. None reported.

Clinical Trials. None reported.

Collaborations/Partnerships. In discussion with a group in Europe interested in using the technology in clinical trials.

Follow-up Applications/Awards. None reported.

PI: LIOTTA, LANCE ALLEN

Institution: **GEORGE MASON UNIVERSITY**

Project #: **R21CA177535**

Title: **Protein Painting Reveals Hidden Protein-Protein Interaction Domains**

Overview. The goal of this project was to develop a new technology called "protein painting," which would allow for rapid screening of protein-protein interaction domains in solution. The new technology would enhance the capacity of scientists to better identify protein interaction surfaces.

Protein painting involves the use of synthetic organic small molecules that bind to proteins with high affinity and mask protease cleavage sites, but don't have access to internal protein-protein contact domains. "Painted" complexes can then be determined directly by mass spectrometry.

Project Aims. The PI *successfully achieved* both project aims, which involved showing the technology to work against three different protein complexes, for which crystallography data exists, and demonstrating that they could correctly identify the binding domains between proteins.

Publications and Citations. Project successes have been documented in one publication, with another in preparation showing the technology outperformed two broadly practiced approaches to studying protein-protein interactions: deuterium exchange mass spectrometry (DXMS) and cross linking mass spectrometry (CLMS).

Licenses and Patents.[30] The PI has filed two patent applications for this technology, and has a new licensing agreement with EMD Millipore to make commercially available kits of the reagents.

Clinical Trials. None reported.

Collaborations/Partnerships. The PI is working with two collaborators: Aleksandra Nita-Lazar, Chief, Cellular Networks Proteomics Unit at NIAID (to verify and validate the strength of the approach); and Eric Sundine at the University of Maryland's Viral Research Institute (to compare DXMS).

Follow-up Applications/Awards. The PI intends to submit an application for further support through an IMAT R33 award to optimize and validate the approach. He has also submitted two other R21 and one R01 grant applications to the NIH, plus applications to the Congressionally Directed Medical Research Program, the National Science Foundation, and the University of Utah utilizing protein paint for biomedical research aims outside of cancer.

[30] Patent applications cited may be for associated technology developed using funding from a previous award.

PI: TAVANA, HOSSEIN; LUKER, GARY D.

Institution: **UNIVERSITY OF AKRON**

Project #: **R21CA182333**

Title: **A Novel High Throughput Tumor Spheroid Microtechnology**

Overview. The goal of the project was to develop a high-throughput system providing a more efficient and standardized method of utilizing tumor spheroids in 3D cultures for screening to test anti-cancer compounds. Existing model systems for 2D *in vitro* culture and mouse models have both proved to have substantial shortcomings as adequate screening models for screening new drugs for cancer. The hope is that 3D spheroids, especially ones that incorporate other cell types in the tumor microenvironment, may be better models and overcome the shortcomings of 2D and mouse-based screening.

Hossein Tavana and Gary Luker proposed to develop an automated, robotically-controlled platform for uniform growth of tumor spheroids, called aqueous two-phase system (ATPS), in 384-well plates for drug screening with more representative cancer models. The approach involved immersing a nanoliter drop of dextran loaded with cancer cells into wells of polyethylene glycol (PEG). Cells proliferate in the dextran to form uniform spheroids, which are now individually addressable by well number. The PIs also proposed to create spheroids of mixed tumor and stromal cells to screen compounds that target tumor-stroma interactions.

Project Aims. The PIs have *not met* the two project aims yet; complications associated with developing appropriate culturing protocols for 3D growth primarily accounted for the limited progress the first year. The complications have been resolved and the PIs are now able to create robust and highly uniform spheroid arrays from both patient samples as well as from xenograft cells. The PIs are now making steady progress toward achieving the two project aims.

Publications and Citations. The PIs have published three manuscripts with two more in preparation.

Licenses and Patents.[31] A patent application for this technology has been filed with the USPTO.

Clinical Trials. None reported.

Collaborations/Partnerships. The PIs are working with two new collaborators, one at their home institution and another at Case Western University.

Follow-up Applications/Awards. An additional $50k grant from the state of Ohio has been issued to explore the commercial potential of this technology. The PI is considering both IMAT R33 and IMAT-SBIR grant support options to further develop and validate this technology.

[31] Patent application cited may be for associated technology developed using funding from a previous award.

Appendix D – History of Evaluation Activities

2007 Feasibility Study for Outcome Evaluation of IMAT Program, Macro International

Macro International conducted a study to assess the feasibility of conducting an outcome evaluation for the IMAT program. As described in the Scope of Work (SOW), Macro's suggested outcome evaluation strategy focused on tracking the development of all technologies that were supported through the IMAT grant mechanisms. Activities during the feasibility study included:

Background information review. Macro reviewed a variety of background information including: FOAs, IMAT website materials, budget history, and awarded grant data.

Literature review. Macro evaluated the feasibility of performing two different types of literature reviews: 1) topic search and 2) author search. These two types are related in that the topic search is filtered by author and the author search is filtered by topic (e.g., IMAT grant relationship).

- **Topic Search.** Macro concluded that a search solely by topic would result in an "unwieldy" number of publications due to the broad number of scientific areas covered by the IMAT program. However, they achieved a manageable number by filtering the topic search by author name (last name and first/second initial). They recommend this approach for consideration in the full-scale evaluation.
- **Author Search.** Macro used an alternate approach to search for publications by author name, using all PD/PIs affiliated with the original grant application, as well as additional collaborators associated with the technologies (they identified the collaborators by using Query View Report (QVR), an IMPAC II module, to identify publications directly affiliated with IMAT grants and noting the authors on those publications). This search defined the set of publications; citation data were determined for each publication. The author search resulted in a proof of concept producing a frequency count of publications and citations and a recommended approach for performing literature reviews of all IMAT grantees.

Interviews with NIH program staff. Macro collected information through several interviews with key program staff. The interviews were designed to elicit information about the degree to which the research environment had changed since the IMAT program inception and whether the focus of the evaluation should be on short-, intermediate-, or long-term goals. The following groups were interviewed:

- **Senior IMAT staff** were asked about program details related to IMAT program structure, history, and changes over time. Senior staff were also asked about how feasibility milestones were established and evaluated, and what type of information could be used in the full-scale evaluation.
- **Other NIH staff and Federal employees** were asked about their role related to the IMAT program and any recommendations for how the IMAT program should be evaluated.
- **IMAT PD/PIs** (Eight grantees total) were interviewed to understand the IMAT program from the grantee's perspective, including information about how the PD/PIs described their technologies and their rationale for choosing their technologies. The interviews also assessed PD/PI level of collaboration and interaction with NIH and other members of the scientific community as well as what types of subsequent funding PD/PIs had applied for and received. Macro obtained feedback on the structure of the IMAT program, grant application process, and establishment of milestones.

2008 Outcome Evaluation Report, SAIC Corporation

In 2008, SAIC Corporation was awarded the contract to complete the first and second stage of the multi-stage evaluation plan. The **first stage** involved 1) reviewing of grant applications; 2) analyzing grant application and award data; 3) reviewing the literature to generate a protocol for interviewing NCI staff; and 4) interviewing NCI staff to learn more about funded projects and the funding decision process. The **second stage** involved interviewing nine IMAT PD/PIs, three from each program area.

Description of the Program. As part of their evaluation activities, SAIC produced several tables, graphs, figures, and charts[32] that more clearly described the program design and intent. Many of these charts and documents are available on the IMAT website.

Case Studies. They also produced several technology specific case studies[33] that are also available on the IMAT website. These case studies covered the following:

- Technology Name
- PI Name
- Institution
- Grant Title
- Grant Number
- Funding Amount
- Dates of Award (Years)
- Description of Technology
- Diagram of Technology
- Description of Impact
- Patent/Licensing Information
- Publication/Citation Information
- Research Funding outside of IMAT
- Description of Current Technology Uses, Dissemination, and Commercialization

Publication and Patent Trends. Appendix 1 of the SAIC evaluation contains information on the publication and patent trends for grants from FY2005 to FY2007. The raw data are unavailable; however, the frequency reports produced from this document could be a checkpoint to validate queries for the evaluation.

Awarded Grants. Appendix 2 of the SAIC evaluation contains a summary of the FY2005 to FY2007 awarded grants. The information presented in Appendix 2 is available directly from IMPAC II and the complete list of grants through FY2013 is available on the IMAT website.[34]

2010 Evaluation Update Report, Science & Technology Policy Institute

In 2010, the Science & Technology Policy Institute (STPI) prepared an evaluation of the IMAT program that built on the activities initiated by SAIC.

Case Studies. STPI prepared six additional case studies for the period of 2008 to 2010 that addressed similar data elements to those included in the SAIC report.

---

[32] http://innovation.cancer.gov/docs/IMAT_Program_Overview.pdf

[33] http://innovation.cancer.gov/about/outputs/tech/index.asp

[34] http://innovation.cancer.gov/awards/

Patents and Publications. Similar to the earlier SAIC evaluation, STPI produced several frequency reports on the number of publications, citations, and patents (applications, provisional, etc.). This analysis was further enhanced by including information on journal impact score.

Other Analyses. The analyses also included a look of how the program contributed to the overall NCI technology development portfolio and the number of first time investigators.

The raw data used to produce these reports is unavailable, however the analysis can provide a checkpoint for Ripple Effect's analyses.

2013 Targeted Evaluation Activities, Thomson Reuters – Custom Analytics Group

In 2013 Thomson Reuters completed evaluation activities to answer three study questions:

1. Are submissions to and awards from the IMAT program significantly unique within the NCI portfolio?
2. Does the program work to support technology development appropriately?
3. Does the program support technologies useful to the cancer research community?

Uniqueness of applications and awards in NCI portfolio. Thomson Reuters compared IMAT program applications and awards to NIH study sections with a similar focus to the IMAT program. Specifically, they looked at applications and awards for FY2012. The PD/PIs who submitted applications were assessed for their record of past cancer-related research and evidence of support for cancer research. Comparison Groups were selected by identifying study sections with a similar focus to the IMAT program.

Effectiveness of program structure. Thomson Reuters reviewed the progress reports of awarded grants to measure individual project outcomes. Progress reports provided data regarding the achievement of progress against proposed milestones. Data were also gathered on IMAT related technologies and patents.

Support of Useful Technologies. The usefulness of the technologies developed through IMAT funding was assessed through elements such as bibliometric indicators of publication impact, evidence of new collaborations, evidence of licensing or other commercialization activity, professional recognitions, and evidence of follow-up applications for support involving the technology developed. In addition, nine projects were randomly selected for case-study interviews.

The evaluation report is helpful in that the methodologies used to establish the Comparison Group for the NCI portfolio was clearly documented. In addition, the data from this evaluation was submitted to NCI and available for other contractors to access.

Many of the results of all four of these evaluation activities are presented in summary on the IMAT website, specifically in the Outputs and Achievements[35] section.

[35] http://innovation.cancer.gov/about/outputs/index.asp

Appendix E – FOAs Included in IMAT and Comparison Groups

The following two tables represents all IMAT FOAs between FY1998 and FY2013 with the number of awards by thematic area by fiscal year.

Table 31. IMAT R21 and R33 FOAs by Thematic Area

FY	IMAT Research			EMAT Research			BIOSP Research		
	FOA	R21 Awards	R33 Awards	FOA	R21 Awards	R33 Awards	FOA	R21 Awards	R33 Awards
1998	PAR98-066	1	0						
	PAR98-067	24	26						
1999	PAR99-100	31	34	PAR99-102	14	21			
2001	PAR01-104	15	21	PAR01-106	20	20			
2005	CA05-002	17	2	CA05-003	8	9	CA05-004	4	2
2006	CA06-002	9	4	CA06-003	8	8	CA06-004	4	3
2007	CA07-001	5	4	CA07-002	9	6	CA07-003	3	0
	CA07-015	8	0	CA07-017/ CA07-018	1	0	CA07-022	1	0
	CA07-016	0	1	CA07-019	4	1	CA07-024	0	0
	CA07-033/ CA07-034	16	2	CA07-035/ CA07-036	9	4	CA07-037/ CA07-038	4	0
2008	CA08-006	16		CA08-007/ CA08-008	11	3	CA08-009/ CA08-010	5	0
2009	CA09-008	14		CA09-006/ CA09-007	7	4	CA09-004/ CA09-005	4	1
2010	CA10-005	16		CA10-003/ CA10-004	11	9	CA10-001/ CA10-002	3	2
2012	CA12-002	20		CA12-002		11	CA12-004/ CA12-005	3	3
2013	CA13-001	9		CA13-002		4	CA13-003/ CA13-004	0	1
Total		**201**	**94**		**102**	**100**		**31**	**12**

Table 32. IMAT SBIR/STTR FOAs by Thematic Area

	IMAT STTR			IMAT SBIR			EMAT STTR			EMAT SBIR			BIOSP STTR			BIOSP SBIR		
	FOA	R41	R42	FOA	R43	R44	FOA	R41	R42	FOA	R43	R44	FOA	R41	R42	FOA	R43	R44
1998	PAR98-066	4	0	PAR98-066	24	2												
1999	PAR99-101	1	1	PAR99-101	19	7												
2001	PAR01-105	2	1	PAR01-104/ PAR01-105	25	9												
	PAR01-107	1	3	PAR01-107	11	1	PAR01-107	0	0	PAR01-106	0	1						
2005	CA05-006	0	1	CA05-006	4	1	CA05-007	0	0	CA05-007	1	0						
2006	CA06-006	0	0	CA06-005	3	2	CA06-006	1	0	CA06-006	3	1						
2007	CA07-007/ CA07-009	0	0	CA07-006	3	0	CA07-009	0	0	CA07-008	2	2	CA07-011	1	1	CA07-010	2	1
	CA07-011/ CA07-044	0	0	CA07-039	4	2	CA07-042	0	0	CA07-041	4	1	CA07-044	1	1	CA07-043	1	0
2008	CA08-012	0	1	CA08-011	2	2							CA08-014	0	0	CA08-013	0	1
2009																		
2010										CA10-013	4	0						
2012																		
2013										PAR13-327	0							
Total		**8**	**7**		**95**	**26**		**1**	**0**		**14**	**5**		**2**	**2**		**3**	**2**

Table 33. Comparison Group FOAs by Fiscal Year and Award Type

The following table represents the FOAs included in Comparison Group with the number of awards by activity type for each FOA by Fiscal Year.

FY	FOA R21/R33 Awards	Number of R21 Awards	Number of R33 Awards	FOA STTR Awards	Number of R41 Awards	Number of R42 Awards	FOA SBIR Awards	Number of R43 Awards	Number of R44 Awards
1998							CA98-022	5	1
1999							PA99-007		1
2000				PAR00-030	1		PA00-018	1	
							PAR00-030	4	1
							PAR00-061	2	
							PAR00-090	4	
2001	CA01-011	1	1	PA01-091	2	1	PAR01-062/PAR01-102	8	4
	PAR01-003	3	1				PA01-052	2	
							PA01-091/PA01-093	16	2
2002	DK02-022	3					PA02-125	6	
	EB02-002	1					PAS02-149		1
	MH02-003	3							
	PAR02-074/PAR02-091	19	1						
2003	PAR03-075	13		PA03-013		1	PA03-013/PA03-021	4	
	PAR03-098	1	1	PAR03-074	1		PAR03-074	3	2
	PAR03-105	4		PAR03-125		2	PAR03-119	1	
	PAR03-124	11	2				PAR03-125	1	2
2004	PA04-095	19	1				PA04-047/PA04-089	1	1

FY	FOA R21/R33 Awards	Number of R21 Awards	Number of R33 Awards	FOA STTR Awards	Number of R41 Awards	Number of R42 Awards	FOA SBIR Awards	Number of R43 Awards	Number of R44 Awards
	PA04-102	5					PA04-094/PA04-127	2	2
							PA04-161	1	
2005	HG05-004	3					AT05-005	1	
2006	AI06-005/AI06-042	17		PA06-121	2	3	PA06-120	7	1
	PA06-243/PA06-388	12					PA06-121	1	
	PA06-398/PA06-463	4	1						
	PA06-519	11							
	PAR06-287	4							
2007	CA07-005	2		PA07-281	1	6	PA07-280	12	
	DC07-002	3							
	AI07-034/AI07-038	15							
	DA08-001/DA08-020	6		PA08-051	1	2	PA08-050	3	
2008	AI08-016/AI08-055	16							
	MH08-050	6							
	PAR08-158	3							
2009	AI09-021	6		PA09-081		2			
	DA09-020	3							
	MH09-021/MH09-130	13							
	MH09-161	6							

FY	FOA R21/R33 Awards	Number of R21 Awards	Number of R33 Awards	FOA STTR Awards	Number of R41 Awards	Number of R42 Awards	FOA SBIR Awards	Number of R43 Awards	Number of R44 Awards
	PA09-119	7							
	PAR09-056/PAR09-057	4							
2010	AI10-011	6		PA10-051	1		PA10-050	4	
	PAS10-274	6							
	PAR10-024	2							
2011	AI11-009/AI11-016	17							
	AI11-024/AI11-027	23	1						
	AI11-032	13							
	DC11-002	2							
	PAR11-177/PAR11-319	9							
2012	AI12-020	18							
	DC12-003	2							
	PAR12-109	3							
	MH12-050	2							
2013	DA13-001	4							
Total		**331**	**9**		**9**	**17**		**89**	**18**

Appendix F – Complete List of FOAs Available for Comparison Group

The following list represents all FOAs between FY1998 and FY2013 that were considered for inclusion in the Comparison Group, sorted by type of grant. FOAs included in the final sample are indicated in the far right column.

Table 34. Full List of FOAs Considered for Comparison Group

Announcement Number	Activity Code	Title	Included in Comparison Group
PA-00-009	R41, R42, R43, R44	COOPERATIVE PROGRAM ON RETINAL DEGENERATIVE DISEASE RESEARCH	
PA-00-018	R43	BIOENGINEERING NANOTECHNOLOGY INITIATIVE	YES
PA-00-084	R41, R42, R43, R44	TECHNOLOGY DEVELOPMENT FOR HIGH RESOLUTION ELECTRON MICROSCOPY	
PA-01-050	R41, R42, R43, R44	SINGLE MOLECULE DETECTION AND MANIPULATION (SBIR/STTR)	
PA-01-052	R43	SBIR ADVANCED TECHNOLOGY - NIAID (SBIR)	YES
PA-01-054	R41, R43	TECHNOLOGIES FOR MONITORING AND PERFORMING RESUSCITATION (SBIR/STTR)	
PA-01-091	R41, R42, R43, R44	FLEXIBLE SYSTEM TO ADVANCE INNOVATIVE RESEARCH FOR CANCER DRUG DISCOVERY BY SMALL BUSINESSES (FLAIR) (SBIR)	YES
PA-01-093	R44	NIDDK EXPANDED AWARDS FOR SBIR-AT-NIDDK (SBIR)	YES
PA-02-027	R43, R44	PHARMACOLOGIC AGENTS AND DRUGS FOR MENTAL DISORDERS (SBIR/STTR)	
PA-02-028	R43, R44	DEVELOPMENT OF PET AND SPECT LIGANDS FOR BRAIN IMAGING (SBIR/STTR)	
PA-02-029	R43, R44	PROBES FOR MICROIMAGING THE NERVOUS SYSTEM (SBIR/STTR)	
PA-02-071	R41, R42, R43, R44	INNOVATIVE TECHNOLOGIES FOR ENHANCING FUNCTION FOR INDIVIDUALS WITH DISABILITIES	
PA-02-075	R41, R42, R43, R44	INNOVATIVE TOXICOLOGY MODELS (SBIR/STTR)	
PA-02-108	R41, R42, R43, R44	STRUCTURAL BIOLOGY OF MEMBRANE PROTEINS SBIR/STTR ANNOUNCEMENT	
PA-02-125	R43, R44	BIOENGINEERING NANOTECHNOLOGY INITIATIVE (SBIR/STTR)	YES
PA-03-001	R43, R44	KNOWLEDGE INTEGRATION ACROSS DISTRIBUTED HETEROGENEOUS DATA SOURCES (SBIR/STTR)	
PA-03-013	R41, R42, R43, R44	SMALL BUSINESS GRANTS FOR IDENTIFYING MOLECULAR SIGNATURES OF CANCER (SBIR)	YES

Announcement Number	Activity Code	Title	Included in Comparison Group
PA-03-021	R41, R42, R43, R44	MOLECULAR TARGETS FOR CANCER DRUG DISCOVERY (SBIR/STTR)	YES
PA-03-030	R41, R42, R43, R44	TELEHEALTH TECHNOLOGIES DEVELOPMENT (SBIR/STTR)	
PA-03-031	R41, R42, R43, R44	SYSTEMS AND METHODS FOR SMALL ANIMAL IMAGING (SBIR/STTR)	
PA-03-049	R41, R43	CHEMICAL SCREENS FOR NEW INDUCERS OF FETAL HEMOGLOBIN (SBIR/STTR)	
PA-03-085	R42, R44	COMPETING CONTINUATION AWARDS OF SBIR/STTR PHASE II GRANTS FOR DEVICE ASSESSMENT OR PRECLINICAL STUDIES (SBIR/STTR)	
PA-03-123	R41, R42, R43, R44	DEVELOPMENT OF DIAGNOSTIC SCREENING TEST FOR SALT SENSITIVITY (SBIR/STTR)	
PA-03-129	R42, R44	COMPETING CONTINUATION AWARDS OF SBIR/STTR PHASE II GRANTS FOR PHARMACOLOGICAL AGENTS AND BIOMARKERS FOR ALCOHOLISM AND ALCOHOL-RELATED DISEASES (SBIR/STTR)	
PA-03-154	R41, R42, R43, R44	SBIR/STTR PHASE II COMPETING CONTINUATION AWARDS (NIDA) (SBIR/STTR)	
PA-04-028	R44	COMPETING CONTINUATION AWARDS OF SBIR PHASE II GRANTS FOR HEART, LUNG, BLOOD, AND SLEEP DISORDERS (SBIR)	
PA-04-047	R41, R42, R43, R44	NCI COMPETING CONTINUATION SBIR/STTR PHASE II GRANTS FOR CANCER DIAGNOSIS, PREVENTION AND TREATMENT (SBIR/STTR)	YES
PA-04-059	R41, R42, R43, R44	TECHNOLOGIES FOR MONITORING AND PERFORMING RESUSCITATION (SBIR/STTR)	
PA-04-063	R41, R42, R43, R44	AN SBIR/STTR INITIATIVE FOR IMAGE-GUIDED CANCER INTERVENTIONS (SBIR/STTR)	
PA-04-064	R41, R42, R43, R44	TECHNOLOGY AND AGING: NIA SBIR/STTR PROGRAM INITIATIVE (SBIR/STTR)	
PA-04-086	R43, R44	HIGH THROUGHPUT TOOLS FOR BRAIN AND BEHAVIOR (SBIR/STTR)	
PA-04-089	R41, R42, R43, R44	NEW TECHNOLOGY FOR PROTEOMICS AND GLYCOMICS (SBIR/STTR)	YES
PA-04-094	R41, R42, R43, R44	NOVEL TECHNOLOGIES FOR IN VIVO IMAGING (SBIR/STTR)	YES
PA-04-127	R43, R44	SBIR ADVANCED TECHNOLOGY - NIAID (SBIR/STTR)	YES

Announcement Number	Activity Code	Title	Included in Comparison Group
PA-04-156	R41, R42, R43, R44	BIOENGINEERING APPROACHES TO ENERGY BALANCE AND OBESITY (SBIR/STTR)	
PA-04-161	R41, R42, R43, R44	MANUFACTURING PROCESSES OF MEDICAL, DENTAL, AND BIOLOGICAL TECHNOLOGIES (SBIR/STTR)	YES
PA-05-003	R41, R42, R43, R44	INTEGRATION OF HETEROGENEOUS DATA SOURCES (SBIR/STTR)	
PA-05-014	R41, R42, R43, R44	MOLECULAR LIBRARIES SCREENING INSTRUMENTATION (SBIR/STTR)	
PA-05-041	R41, R42, R43, R44	SMALL BUSINESS INNOVATION RESEARCH (SBIR) AND SMALL BUSINESS TECHNOLOGY TRANSFER (STTR) TO IMPROVE THE CHEMISTRY AND TARGETED DELIVER OF RNAI MOLECULES (SBIR/STTR)	
PA-05-044	R41, R42, R43, R44	DIRECTED STEM CELL DIFFERENTIATION FOR CELL BASED THERAPIES FOR HEART, LUNCH, BLOOD, AND AGING DISEASES (SBIR/STTR)	
PA-05-087	R41, R42, R43, R44	DRUG DELIVERY SYSTEMS FOR OROFACIAL DISEASE (SBIR/STTR)	
PA-05-120	R41, R42, R43, R44	PROBES FOR MICROIMAGING THE NERVOUS SYSTEM (SBIR/STTR)	
PA-05-121	R41, R42, R43, R44	PHARMACOLOGIC AGENTS AND DRUGS FOR MENTAL DISORDERS (SBIR/STTR)	
PA-05-122	R41, R42, R43, R44	DEVELOPMENT OF PET AND SPECT LIGANDS FOR BRAIN IMAGING (SBIR/STTR)	
PA-95-001	P01, R01, R41, R42, R43, R44	FACTORS THAT DETERMINE THERAPEUTIC DRUG BIOAVAILABILITY	
PA-99-004	P01, R01, R41, R42, R43, R44	STRUCTURAL BIOLOGY OF MEMBRANE PROTEINS	
PA-99-007	R43	PROBES AND INSTRUMENTS FOR MICRO-IMAGING THE BRAIN	YES
PA-99-048	R41, R42, R43, R44	TECHNOLOGIES TO IMPROVE THE UTILITY OF ANIMAL MODELS	
PA-99-083	R41, R42, R43, R44	DEVELOPMENT OF DIGITAL MAMMOGRAPHY DISPLAYS AND WORKSTATIONS (SBIR/STTR)	
PA-99-084	R41, R43	STUDY AND CONTROL OF MICROBIAL BIOFILMS (SBIR/STTR)	
PA-99-117	R41, R42, R43, R44	PROTEIN STRUCTURE INITIATIVE (STRUCTURAL GENOMICS) (SBIR/STTR)	

Announcement Number	Activity Code	Title	Included in Comparison Group
PAR-00-030	R41, R42, R43, R44	FLEXIBLE SYSTEM TO ADVANCE INNOVATIVE RESEARCH FOR CANCER DRUG DISCOVERY BY SMALL BUSINESSES (FLAIR) (SBIR)	YES
PAR-00-061	R41, R42, R43, R44	MOLECULAR TARGET DRUG DISCOVERY FOR CANCER: SMALL BUSINESS GRANTS (SBIR)	YES
PAR-00-090	R41, R42, R43, R44	DEVELOPMENT OF NOVEL IMAGING TECHNOLOGIES: (SBIR/STTR) INITIATIVE (SBIR/STTR)	YES
PAR-00-126	R43	SBIR ADVANCED TECHNOLOGY - NIAID (SBIR)	
PAR-01-004	R41, R42, R43, R44	INNOVATIVE TOXICOLOGY MODELS FOR DRUG EVALUATION (SBIR/STTR)	
PAR-01-006	R41, R42, R43, R44	FUNCTIONAL TISSUE ENGINEERING FOR HEART, VASCULAR, LUNG, BLOOD AND SLEEP DISORDERS AND DISEASES (SBIR/STTR)	
PAR-01-062	R41, R42, R43, R44	CANCER PROGNOSIS AND PREDICTION (SBIR/STTR)	YES
PAR-01-102	R41, R42, R43, R44	DEVELOPMENT OF NOVEL TECHNOLOGIES FOR IN VIVO IMAGING (SBIR/STTR)	YES
PAR-01-105	R41, R42, R43, R44	INNOVATIVE TECHNOLOGIES FOR THE MOLECULAR ANALYSIS OF CANCER (SBIR/STTR)	
PAR-01-107	R41, R42, R43, R44	APPLICATIONS OF INNOVATIVE TECHNOLOGIES FOR THE MOLECULAR ANALYSIS OF CANCER (SBIR/STTR)	
PAR-03-074	R41, R42, R43, R44	FLEXIBLE SYSTEM TO ADVANCE INNOVATIVE RESEARCH FOR CANCER DRUG DISCOVERY BY SMALL BUSINESSES (FLAIR) (SBIR/STTR)	YES
PAR-03-119	R41, R42, R43, R44	INNOVATIONS IN BIOMEDICAL COMPUTATIONAL SCIENCE AND TECHNOLOGY (SBIR/STTR)	YES
PAR-03-125	R41, R42, R43, R44	NOVEL TECHNOLOGIES FOR IN VIVO IMAGING (SBIR/STTR)	YES
PAR-98-066	R41, R42, R43, R44	INNOVATIVE TECHNOLOGIES FOR THE MOLECULAR ANALYSIS OF CANCER (SBIR/STTR)	
PAR-98-068	R41, R42, R43, R44	ENGINEERED ISOGENIC CELL LINES WITH RELEVANT CANCER TARGETS	
PAR-98-073	R43	SMALL BUSINESS INNOVATION RESEARCH ADVANCED TECHNOLOGY: NIAID (SBIR/STTR)	
PAR-99-020	R41, R42, R43, R44	NON-MAMMALIAN ORGANISMS AS MODELS FOR ANTICANCER DRUG DISCOVERY (SBIR/STTR)	
PAR-99-052	R43, R44	ADVANCED X-RAY DETECTORS FOR SYNCHROTRON-BASED STRUCTURAL BIOLOGY (SBIR)	

Announcement Number	Activity Code	Title	Included in Comparison Group
PAR-99-101	R41, R42, R43, R44	INNOVATIVE TECHNOLOGIES FOR THE MOLECULAR ANALYSIS OF CANCER (SBIR/STTR)	
PAR-99-103	R41, R42, R43, R44	APPLICATIONS OF INNOVATIVE TECHNOLOGIES FOR THE MOLECULAR ANALYSIS OF CANCER (SBIR/STTR)	
PAR-99-149	R41, R42, R43, R44	DIAGNOSTIC IMAGING AND GUIDED THERAPY IN PROSTATE CANCER (SBIR/STTR)	
PAS-02-149	R41, R42, R43, R44	SMALL BUSINESS BIODEFENSE PROGRAM (SBIR/STTR)	YES
PAS-05-131	R41, R42, R43, R44	APPLICATIONS OF IMAGING AND SENSOR TECHNOLOGIES FOR CLINICAL AGINE RESEARCH (SBIR/STTR)	
RFA-AA-02-012	R43	ALCOHOL SENSING AND DATA ANALYSIS SYSTEM (SBIR/STTR)	
RFA-AA-03-003	R41, R43	SMALL BUSINESS INITIATIVE FOR ALCOHOL PROTEOMICS (SBIR)	
RFA-AA-03-005	R41, R43	MEDICATIONS DEVELOPMENT TO TREAT ALCOHOLISM AND ALCOHOL-RELATED DISEASES (SBIR/STTR)	
RFA-AA-04-002	R41, R42, R43, R44	MEDICATIONS DEVELOPMENT TO TREAT ALCOHOLISM (SBIR/STTR)	
RFA-AA-05-002	R43, R44	INITIATIVE FOR ALCOHOL SENSING AND DATA ANALYSIS SYSTEM (SBIR)	
RFA-AA-06-001	R41, R42, R43, R44	GENOMIC, PROTEOMIC, AND METABOLOMIC FINGERPRINTS AS ALCOHOL BIOMARKERS (SBIR/STTR)	
RFA-AI-00-008	R43	SMALL BUSINESS INNOVATION RESEARCH: ANIMAL MODELS OF HCV INFECTION (SBIR/STTR)	
RFA-AI-04-005	R42, R44	NIAID COMPETING CONTINUATION OF SBIR/STTR PH II AWARDS (SBIR/STTR)	
RFA-AI-99-001	R43	SMALL BUSINESS INNOVATION RESEARCH: ANIMAL MODELS OF HCV INFECTION (SBIR/STTR)	
RFA-AT-00-003	R42, R44	BOTANICAL PRODUCTS DEVELOPMENT (SBIR/STTR)	
RFA-AT-05-005	R43	IMPROVING MEASUREMENT TOOLS FOR STERNAL SKIN CONDUCTANCE AND HOT FLASHES: PHASE I SBIR (SBIR/STTR)	YES
RFA-CA-01-016	R41, R42, R43, R44	DEVELOPMENT OF HIGH-YIELD TECHNOLOGIES FOR ISOLATING EXFOLIATED CELLS IN BODY FLUIDS (SBIR/STTR)	
RFA-CA-05-006	R41, R42, R43, R44	INNOVATIVE TECHNOLOGIES FOR MOLECULAR ANALYSIS OF CANCER (SBIR/STTR)	

Announcement Number	Activity Code	Title	Included in Comparison Group
RFA-CA-05-007	R41, R42, R43, R44	APPLICATION OF EMERGING TECHNOLOGIES FOR CANCER RESEARCH (SBIR/STTR)	
RFA-CA-05-008	R41, R42, R43, R44	INNOVATIONS IN CANCER SAMPLE PREPARATION (SBIR/STTR)	
RFA-CA-06-001	R41, R42, R43, R44	CIRCULATING CELLS AND DNA IN CANCER DETECTION (SBIR/STTR)	
RFA-CA-06-005	R41, R42, R43, R44	INNOVATIVE TECHNOLOGIES FOR MOLECULAR ANALYSIS OF CANCER (SBIR/STTR)	
RFA-CA-06-006	R41, R42, R43, R44	APPLICATION OF EMERGING TECHNOLOGIES FOR CANCER RESEARCH (SBIR/STTR)	
RFA-CA-06-007	R41, R42, R43, R44	INNOVATIONS IN CANCER SAMPLE PREPARATION (SBIR/STTR)	
RFA-CA-98-022	R41, R42, R43, R44	FLEXIBLE SYSTEM TO ADVANCE INNOVATIVE RESEARCH FOR CANCER DRUG DISCOVERY BY SMALL BUSINESSES (SBIR)	YES
RFA-DA-03-015	R41, R42, R43, R44	IMMUNOTHERAPY FOR ADDICTION TREATMENT (SBIR/STTR)	
RFA-DK-03-009	R41, R42, R43, R44	NONINVASIVE MEASUREMENT OF IRON BY MAGNETIC RESONANCE IMAGING (SBIR/STTR)	
RFA-DK-03-020	R41, R42, R43, R44	SMALL BUSINESS INNOVATION RESEARCH (SBIR) AND SMALL BUSINESS TECHNOLOGY TRANSFER (STTR) TO DEVELOP NEW THERAPIES FOR TYPE 1 DIABETES AND ITS COMPLICATIONS (SBIR/STTR)	
RFA-DK-05-010	R41, R42, R43, R44	SMALL BUSINESS INNOVATION RESEARCH (SBIR) AND SMALL BUSINESS TECHNOLOGY TRANSFER (STTR) TO DEVELOP NEW THERAPEUTICS AND MONITORING TECHNOLOGIES FOR TYPE 1 DIABETES (T1D) AND ITS COMPLICATIONS (SBIR/STTR)	
RFA-ES-03-008	R41, R42, R43, R44	E-LEARNING FOR HAZMAT AND EMERGENCY RESPONSE (SBIR/STTR)	
RFA-ES-04-004	R41, R42, R43, R44	E-LEARNING FOR HAZMAT AND EMERGENCY RESPONSE (SBIR/STTR)	
RFA-ES-05-003	R41, R42, R43, R44	E-LEARNING FOR HAZMAT AND EMERGENCY RESPONSE (SBIR/STTR)	
RFA-EY-02-002	R41, R42, R43, R44	INNOVATIVE STRATEGIES AND ASSISTIVE TECHNOLOGIES FOR ENHANCED VISUAL FUNCTION (SBIR/STTR)	
RFA-HD-03-013	R41, R42, R43, R44	ACCESSIBLE HEALTH PROMOTION AND FITNESS FOR PERSONS WITH DISABILITIES (SBIR/STTR)	

Announcement Number	Activity Code	Title	Included in Comparison Group
RFA-HD-03-014	R41, R43	INNOVATIVE TECHNOLOGIES FOR PEDIATRIC CRITICAL CARE AND REHABILITATION (SBIR/STTR)	
RFA-HD-03-019	R41, R43	TRAINING MATERIALS ON SURGICAL AMPUTATIONS, PROSTHETICS AND ORTHOTICS (SBIR/STTR)	
RFA-HD-03-023	R41, R43	INNOVATIONS IN POWERED MOBILITY DEVICES (SBIR/STTR)	
RFA-HD-04-018	R41, R43	MEASUREMENT TOOLS FOR ALTERED AUTONOMIC FUNCTION IN SPINAL CORD INJURY AND DIABETE (SBIR/STTR)	
RFA-RR-99-004	R43, R44	ADVANCED NMR SPECTROSCOPY INSTRUMENTATION	
PA-06-120	R43, R44	PHS 2006-02 OMNIBUS SOLICITATION OF THE NIH, CDC, AND FDA FOR SMALL BUSINESS INNOVATION RESEARCH GRANT APPLICATIONS (SBIR)	YES
PA-06-121	R41, R42	PHS 2006-2 OMNIBUS SOLICITATION OF THE NIGH FOR SMALL BUSINESS TECHNOLOGY TRANSFER GRANT APPLICATIONS (STTR)	YES
PA-07-280	R43, R44	PHS 2007-02 OMNIBUS SOLICITATION OF THE NIH, CDC, AND FDA FOR SMALL BUSINESS INNOVATION RESEARCH GRANT APPLICATIONS (SBIR)	YES
PA-07-281	R41, R42	PHS 2007-02 OMNIBUS SOLICATION OF THE NIH FOR SMALL BUSINESS TECHNOLOGY TRANSFER GRANT APPLICATIONS (STTR)	YES
PA-08-050	R43, R44	PHS 2008-02 OMNIBUS SOLICITATION OF THE NIH, CDC, AND FDA FOR SMALL BUSINESS INNOVATION RESEARCH GRANT APPLICATIONS (SBIR)	YES
PA-08-051	R41, R42	PHS 2008-02 OMNIBUS SOLICATION OF THE NIH FOR SMALL BUSINESS TECHNOLOGY TRANSFER GRANT APPLICATIONS (STTR)	YES
PA-09-080	R43, R44	PHS 2009-02 OMNIBUS SOLICITATION OF THE NIH, CDC, AND FDA FOR SMALL BUSINESS INNOVATION RESEARCH GRANT APPLICATIONS (SBIR)	
PA-09-081	R41, R42	PHS 2009-02 OMNIBUS SOLICATION OF THE NIH FOR SMALL BUSINESS TECHNOLOGY TRANSFER GRANT APPLICATIONS (STTR)	YES
PA-10-050	R43, R44	PHS 2010-02 OMNIBUS SOLICITATION OF THE NIH, CDC, AND FDA FOR SMALL BUSINESS INNOVATION RESEARCH GRANT APPLICATIONS (SBIR)	YES
PA-10-051	R41, R42	PHS 2010-02 OMNIBUS SOLICATION OF THE NIH FOR SMALL BUSINESS TECHNOLOGY TRANSFER GRANT APPLICATIONS (STTR)	YES

Announcement Number	Activity Code	Title	Included in Comparison Group
PA-11-096	R43, R44	PHS 2011-02 OMNIBUS SOLICITATION OF THE NIH, CDC, AND FDA FOR SMALL BUSINESS INNOVATION RESEARCH GRANT APPLICATIONS (SBIR)	
PA-11-097	R41, R42	PHS 2011-02 OMNIBUS SOLICATION OF THE NIH FOR SMALL BUSINESS TECHNOLOGY TRANSFER GRANT APPLICATIONS (STTR)	
PA-12-088	R43, R44	PHS 2012-02 OMNIBUS SOLICITATION OF THE NIH, CDC, AND FDA FOR SMALL BUSINESS INNOVATION RESEARCH GRANT APPLICATIONS (SBIR)	
PA-12-089	R41, R42	PHS 2012-02 OMNIBUS SOLICATION OF THE NIH FOR SMALL BUSINESS TECHNOLOGY TRANSFER GRANT APPLICATIONS (STTR)	
PA-13-088	R43, R44	PHS 2013-02 OMNIBUS SOLICITATION OF THE NIH, CDC, AND FDA FOR SMALL BUSINESS INNOVATION RESEARCH GRANT APPLICATIONS (SBIR)	
PA-13-089	R41, R42	PHS 2013-02 OMNIBUS SOLICATION OF THE NIH FOR SMALL BUSINESS TECHNOLOGY TRANSFER GRANT APPLICATIONS (STTR)	
PA-13-234	R43, R44	REISSUE PHS 2013-02 OMNIBUS SOLICITATION OF THE NIH, CDC, AND FDA FOR SMALL BUSINESS INNOVATION RESEARCH GRANT APPLICATIONS (SBIR)	
PA-13-235	R41, R42	REISSUE PHS 2013-02 OMNIBUS SOLICATION OF THE NIH FOR SMALL BUSINESS TECHNOLOGY TRANSFER GRANT APPLICATIONS (STTR)	
PA-04-095	R21/R33	NOVEL TECHNOLOGIES FOR IN VIVO IMAGING	YES
PA-04-102	R21/R33, R33	PHASED APPLICATION AWARDS IN CANCER PROGNOSIS AND PREDICTION	YES
PA-06-109	R21/R33	PHASED INNOVATION AWARDS IN AIDS VACCINE RESEARCH	
PA-06-243	R21/R33	NEW APPROACHES TO NON-VIRAL SYSTEMS FOR GENE TRANSFER APPLICATIONS FOR HEART, LUNG, AND BLOOD DISEASES	YES
PA-06-388	R21/R33	HIV PROTEINS AND THEIR CELLULAR BINDING PARTNERS	YES
PA-06-398	R21/R33	NOVEL TECHNOLOGIES FOR IN VIVO IMAGING	YES
PA-06-434	R21/R33	PHASED INNOVATION RESEARCH IN CANCER PROGNOSIS AND PREDICTION	

Announcement Number	Activity Code	Title	Included in Comparison Group
PA-06-463	R21/R33	DEVELOPMENT AND APPLICATION OF PET AND SPECT IMAGING LIGANDS AS BIOMARKERS FOR DRUG DISCOVERY AND FOR PATHOPHYSIOLOGICAL STUDIES OF CNS DISORDERS	YES
PA-06-519	R21/R33	PHASED INNOVATIONS AWARDS IN AIDS VACCINE RESEARCH	YES
PA-09-119	R21/R33	PHASED INNOVATION AWARD PROGRAM IN AIDS VACCINE RESEARCH	YES
PAR-01-003	R21/R33	INNOVATIVE TOXICOLOGY MODELS FOR DRUG EVALUATION: EXPLORATORY / DEVELOPMENTAL GRANTS AND PHASED INNOVATION AWARD	YES
PAR-02-074	R21, R21/R33, R33	INNOVATIVE TOXICOLOGY MODELS FOR DRUG EVALUATION: EXPLORATORY / DEVELOPMENTAL GRANTS AND PHASED INNOVATION AWARD	YES
PAR-02-091	R21/R33	TECHNOLOGY DEVELOPMENT FOR BIOMEDICAL APPLICATIONS: PHASED INNOVATION AWARD	YES
PAR-03-075	R21, R21/R33	TECHNOLOGY DEVELOPMENT FOR BIOMEDICAL APPLICATIONS	YES
PAR-03-098	R21/R33	PHASED APPLICATION AWARDS IN CANCER PROGNOSIS AND PREDICTION	YES
PAR-03-105	R21/R33	RESEARCH GRANTS FOR CLINICAL STUDIES OF KIDNEY DISEASES	YES
PAR-03-124	R21/R33	NOVEL TECHNOLOGIES FOR IN VIVO IMAGING	YES
PAR-06-287	R21/R33	INNOVATIVE APPLICATION OF NANOTECHNOLOGY TO HEART, LUNG, BLOOD, AND SLEEP DISORDERS	YES
PAR-08-158	R21/R33	MOUSE MODELS CONTAINING HUMAN ALLELES: NOVEL TOOLS TO STUDY BRAIN FUNCTION	YES
PAR-09-056	R21/R33	IMPROVING INTERVENTION POSSIBILITIES FOR COMMUNICATION DISORDERS	YES
PAR-09-057	R21/R33	IMPROVING INTERVENTION POSSIBILITIES FOR COMMUNICATION DISORDERS	YES
PAR-10-024	R21/R33	DEVELOPMENT AND APPLICATION OF PET AND SPECT IMAGING LIGANDS AS BIOMARKERS FOR DRUG DISCOVERY AND FOR PATHOPHYSIOLOGICAL STUDIES OF CNS DISORDERS	YES
PAR-11-177	R21/R33	TRANSLATIONAL RESEARCH FO RTHE DEVELOPMENT OF NOVEL INTERVENTIONS FOR MENTAL DISORDERS	YES

Announcement Number	Activity Code	Title	Included in Comparison Group
PAR-11-319	R21/R33	SCALABLE ASSAYS FOR UNBIASED IN VITRO ANALYSIS OF NEUROBIOLOGICAL FUNCTION	YES
PAR-12-109	R21/R33	TARGETING PERSISTENT HIGH RESERVOIRS (TaPHIR)	YES
PAR-12-204	R01, R03, R15, R21, R21/R33, R37, U01	ESTABLISHING SHARING OF HUMAN GRAIN IMAGE DATA RELEVANT TO DRUG ADDICTION (ADMINISTRATIVE SUPPLEMENT)	
PAS-10-274	R21/R33	EARLY CAREER AWARD IN CHEMISTRY OF DRUG ABUSE AND ADDICTION (ECHEM)	YES
RFA-AI-06-005	R21/R33	MICROBICIDE INNOVATION PROGRAM (MIP)	YES
RFA-AI-06-042	R21/R33	MICROBICIDE INNOVATION PROGRAM (MIP II)	YES
RFA-AI-07-034	R21/R33	MICROBICIDE INNOVATION PROGRAM (MIP III)	YES
RFA-AI-07-038	R21/R33	RADIATION COMBINED INJURY: RADIATION EXPOSURE IN COMBINATION WITH BURN, WOUND, TRAUMA, OR INFECTION	YES
RFA-AI-08-016	R21/R33	MICROBICIDE INNOVATION PROGRAM (MIP IV)	YES
RFA-AI-08-055	R21/R33	INNOVATIVE APPROACHES TO TARGET IDENTIFICATION AND ASSAY DEVELOPMENT FOR FUNDAL DIAGNOSIS	YES
RFA-AI-09-021	R21/R33	MICROBICIDE INNOVATION PROGRAM (MIP V)	YES
RFA-AI-10-011	R21/R33	MICROBICIDE INNOVATION PROGRAM (MIP VI)	YES
RFA-AI-11-009	R21/R33	TARGETING RESISTANCE IN SELECT GRAM-NEGATIVE PATHOGENS	YES
RFA-AI-11-016	R21/R33	COMBINED MULTIPURPOSE STRATEGIES FOR SEXUAL AND REPRODUCTIVE HEALTH	YES
RFA-AI-11-024	R21/R33	IMPROVED DIAGNOSTIC CAPABILITIES FOR SELECT BIODEFENSE AND EMERGING PATHOGENS	YES
RFA-AI-11-027	R21/R33	THERAPEUTICS FOR NEUROTROPIC BIODEFENSE TOXINS AND PATHOGENS	YES
RFA-AI-11-032	R21/R33	HOST-TARGETED INTERVENTIONS AS THERAPEUTICS FOR INFECTIOUS DISEASES	YES
RFA-AI-12-020	R21/R33	PARTNERSHIPS FOR INTERVENTIONS TO TREAT CHRONIC, PERSISTENT, AND LATENT INFECTIONS	YES
RFA-AI-13-019	R21/R33	DRUG TARGET DEVELOPMENT AND VALIDATION FOR ANTIMICROBIAL-RESISTANT PATHOGENS	
RFA-AI-14-015	R21/R33	DEVELOPMENT OF NOVEL THERAPEUTICS FOR SELECT ANAEROBIC PROTOZOA	
RFA-AI-14-026	R21/R33	DEVELOPMENT OF NOVEL THERAPEUTICS FOR SELECT PATHOGENS	

Announcement Number	Activity Code	Title	Included in Comparison Group
RFA-CA-01-011	R21, R21/R33, R33	TECHNOLOGIES FOR COMPREHENSIVE, SENSITIVE, AND QUANTITATIVE PROTEIN ANALYSIS IN HUMAN TUMORS: PHASED INNOVATION	YES
RFA-CA-07-002	R21, R21/R33, R33	APPLICATION OF EMERGING TECHNOLOGIES FOR CANCER RESEARCH	
RFA-CA-07-003	R21, R21/R33, R33	INNOVATIONS IN CANCER SAMPLE PREPARATION	
RFA-CA-07-005	R01, R21, R21/R33	ADVANCED PROTEOMIC PLATFORMS AND COMPUTATIONAL SCIENCES FOR THE NIC CLINICAL PROTEOMIC TECHNOLOGIES INITIATIVE	YES
RFA-CA-07-019	R21/R33	APPLICATION OF EMERGING TECHNOLOGIES FOR CANCER RESEARCH	
RFA-CA-07-024	R21/R33	INNOVATIONS IN CANCER SAMPLE PREPARATION	
RFA-DA-08-001	R21/R33	COLLABORATIVE RESEARCH TO EXPLORE NEW USES FOR EXISTING RADIOLIGANDS	YES
RFA-DA-08-020	R21/R33	FACILITATING SELF-CONTROL OF SUBSTANCE ABUSE RELATED BRAIN ACTIVITY THROUGH REAL-TIME MONITORING OF fMRI SIGNALS	YES
RFA-DA-09-020	R21/R33	SECONDARY DATA ANALYSES FOR SUBSTANCE ABUSE RESEARCH	YES
RFA-DA-13-001	R21/R33	PHASED SERVICES RESEARCH STUDIES OF DRUG USE PREVENTION, ADDICTION TREATMENT, AND HIV IN AN ERA OF HEALTH CARE REFORM	YES
RFA-DC-07-002	R21/R33	NIDCD R21/R33 PHASED INFRASTRUCTURE GRANT FOR PATIENT-ORIENTED RESEARCH	YES
RFA-DC-10-002	R21/R33	ACCESSIBLE AND AFFORDABLE HEARING HEALTH CARE	
RFA-DC-11-002	R21/R33	IDENTIFICATION OF IMMUNE-MEDIATED CAUSES OF SENSORINEURAL HEARING LOSS	YES
RFA-DC-12-003	R21/R33	NIDCD RESEARCH ON HEARING HEALTH CARE	YES
RFA-DK-02-022	R21, R21/R33, R33	BENCH TO BEDSIDE RESEARCH ON TYPE 1 DIABETES AND ITS COMPLICATIONS	YES
RFA-EB-02-001	R01, R21/R33	RESEARCH AND DEVELOPMENT OF SYSTEMS AND METHODS FOR MOLECULAR IMAGING	
RFA-EB-02-002	R01, R21/R33	SENSOR DEVELOPMENT AND VALIDATION	YES
RFA-ES-13-013	R21/R33	VALIDATION AND DEMONSTRATION OF DEVICES FOR ENVIRONMENTAL ASSESSMENT	

Announcement Number	Activity Code	Title	Included in Comparison Group
RFA-ES-14-006	R21/R33	INNOVATIVE APPROACHES FOR THE IDENTIFICATION OF MITOCHONDRIA-CELL SIGNALING NETWORKS IN RESPONSE TO ENVIRONMENTAL STRESS	
RFA-HG-05-003	R01, R21, R21/R33	NEAR-TERM TECHNOLOGY DEVELOPMENT FOR GENOME SEQUENCING	
RFA-HG-05-004	R01, R21, R21/R33	REVOLUTIONARY GENOME SEQUENCING TECHNOLOGIES – THE $1,000 GENOME	YES
RFA-HG-06-017	R21/R33	NEAR-TERM TECHNOLOGY DEVELOPMENT FOR GENOME SEQUENCING	
RFA-HG-06-022	R21/R33	REVOLUTIONARY GENOME SEQUENCING TECHNOLOGIES – THE $1,000 GENOME	
RFA-HL-13-027	R21/R33	FUNCTIONAL ASSAYS TO SCREEN GENOMIC HITS	
RFA-MH-02-003	R21/R33	DEVELOPMENT OF PET AND SPECT LIGANDS FOR BRAIN IMAGING	YES
RFA-MH-08-050	R21/R33	MOUSE MODELS CONTAINING HUMAN ALLELES: NOVEL TOOLS TO STUDY BRAIN FUNCTION	YES
RFA-MH-09-021	R21/R33	NOVEL INTERVENTIONS FOR NEURODEVELOPMENTAL DISORDERS	YES
RFA-MH-09-130	R21/R33	EXPLORATORY STUDIES OF INDUCED PLURIPOTENT STEMS (iPS) CELLS FROM HEALTHY AND MENTAL HEALTH PATIENT POPULATIONS	YES
RFA-MH-09-161	R21/R33	NOVEL INTERVENTIONS FOR NEURODEVELOPMENTAL DISORDERS	YES
RFA-MH-12-050	R21/R33	OPTIMIZING FIDELITY OF EMPIRICALLY-SUPPORTED BEHAVIORAL TREATMENTS FOR MENTAL DISORDERS	YES
RFA-MH-14-080	R21/R33	GUT-MICROBIOME-BRAIN INTERACTIONS AND MENTAL HEALTH	
RFA-MH-15-850	R21/R33	GUT-MICROBIOME-BRAIN INTERACTIONS AND MENTAL HEALTH	
RFA-RM-11-024	R21/R33	PHASED ECONOMIC STUDIES ANCILLARY TO PLANNED HEALTH CARE DELIVERY AND FINANCING PILOTS, DMONSTRATIONS, AND OTHER EXPERIMENTS	

Appendix G – Archival Data Collection Methodology

Obtaining Grant Information

Data on IMAT projects were pulled using a query summarizing projects by the RFA number. Specifically, the syntax below was used. To obtain the full list, one can remove the count function and group by statement to get the full list.

```
select a.RFA_PA_NUMBER, count(a.appl_id)
from appls_t a
where a.RFA_PA_NUMBER in ('CA05-002','CA05-003','CA05-004','CA05-006','CA05-007','CA06-002','CA06-003','CA06-004','CA06-005','CA06-006','CA07-001','CA07-002','CA07-003','CA07-006','CA07-007','CA07-008','CA07-009','CA07-010','CA07-011','CA07-015','CA07-016','CA07-017','CA07-018','CA07-019','CA07-022','CA07-023','CA07-024','CA07-033','CA07-034','CA07-035','CA07-036','CA07-037','CA07-038','CA07-039','CA07-040','CA07-041','CA07-042','CA07-043','CA07-044','CA08-006','CA08-007','CA08-008','CA08-009','CA08-010','CA08-011','CA08-012','CA08-013','CA08-014','CA09-004','CA09-005','CA09-006','CA09-007','CA09-008','CA10-002','CA10-003','CA10-004','CA10-005','CA10-013','CA13-001','CA13-002','CA13-003','CA13-004','PAR01-104','PAR01-105','PAR01-106','PAR01-107','PAR98-067','PAR99-100','PAR99-102','PAR13-327','PAR98-066','PAR99-101','CA10-001','CA12-002','CA12-003','CA12-004','CA12-005')
group by a.RFA_PA_NUMBER
```

Updates to the Funding Opportunity Announcement Table

- Source Documents*: IMAT SOW_Appendix B_IMAT Stats.docx* ; *S1_IMAT FOA History.docx*
    - Source documents contained tables with the various IMAT RFA\PAs Numbers, Activity Code (e.g., R21, R33), Thematic Area (IMAT, EMAT, etc.) and the number of awards.
    - Remaining information needed to fill in the gaps was obtained from the RFA/PA document published online; each RFA's URL followed a standard format (e.g., http://grants.nih.gov/grants/guide/pa-files/**PAR-13-327**.html) with the bolded text representing the RFA number.
        - Lookup tables were developed for Thematic Area and Activity Code
    - Data were copied into a local MS Access database. **(Local IMAT FOAs)**
    - A linked copy of the IMAT FOA SharePoint list was exported to Access **(IMAT FOAs)**
    - The Schema/field types for the local database was matched to the design of the SharePoint list.
        - Once the two schema were matched the data from Local IMAT FOAs was copied to IMAT FOAs

INSERT INTO [IMAT FOAs] ([FY Released], [RFA/PA Number], [FOA Title], [FOA Link], [Purpose], [Previous FOA], [Electronic Application], [Posted Date], [Open Date], [Expiration Date], [Notes], [FOA Number], [Council Number], [Activity Code], [Companions], [Thematic Area]) SELECT [Local IMAT FOAs].[FY Released], [Local IMAT FOAs].[RFA/PA Number], [Local IMAT FOAs].[FOA Title], [Local IMAT FOAs].[Local IMAT FOAs].[Local IMAT FOAs].[FOA Link], [Local IMAT FOAs].[Purpose], [Local IMAT FOAs].[Previous

FOA], [Local IMAT FOAs].[Electronic Application], [Local IMAT FOAs].[Posted Date],[Local IMAT FOAs].[Open Date], [Local IMAT FOAs].[Expiration Date], [Local IMAT FOAs].[Notes], [Local IMAT FOAs].[FOA Number], [Local IMAT FOAs].[Council Number], [Local IMAT FOAs].[Activity Code], [Local IMAT FOAs].[Companions], [Local IMAT FOAs].[Thematic Area], FROM [Local IMAT FOAs];

- A test set of 5 records was uploaded to SharePoint. Once the test passed quality checks, the remaining 72 FOA records were uploaded.

Updates to Institution Table

- Source Documents: The SharePoint list **IMAT Institutions** already existed and was populated.
  - This list was imported as a linked table into MS Access in order to QC the list as well as enable fields within the list to be built into the relationships for the rest of the database. Changes to this linked table were automatically updated to the IMAT Evaluation SharePoint List.
  -

Updates to the PD/PI Table

- Source Documents: The SharePoint List IMAT PD/PIs already existed and was populated.
  - This list was imported as a linked table into MS Access in order to QC the list as well as enable fields within the list to be built into the relationships for the rest of the database. Changes to this linked table were automatically updated to the IMAT Evaluation SharePoint List.
  - During the course of managing the evaluation's web-based survey, it was discovered that a number of the e-mail addresses for the PD/PIs on file were outdated.
    - As New e-mail addresses were obtained they were entered into an Excel spreadsheet (*IMAT Email Addresses from Survey effort_6.30.15.xlsx*)
    - The goal was to have a record of the Current PI e-mail address for all PD/PIs and a record of the Old e-mail address if their e-mail had changed. Note New e-mail addresses were not found for all PD/PIs that had inaccurate or invalid e-mails.
    - Updates to the PI e-mail addresses took place in several steps
      - A local copy of the IMAT PD/PIs Table **(tbl_IMAT_PI/PDs)** was made so that all changes could be QCed prior to upload to the IMAT Evaluation SharePoint site.
      - A second table containing the New PI e-mails from *IMAT Email Addresses from Survey effort_6.30.15.xlsx* was imported to MS Access as **tbl_PIemails.**
      - The Current e-mail was updated using the following statement:

UPDATE [tbl_IMAT_PI/PDs] LEFT JOIN tbl_PIemails ON [tbl_IMAT_PI/PDs].[Profile Person ID]=tbl_PIemails.[Profile Person ID] SET [tbl_IMAT_PI/PDs].[Current E-mail] = tbl_PIemails.[E-mail

Address] WHERE [tbl_IMAT_PI/PDs].[Current E-mail]<>tbl_PIemails.[E-mail Address];

- Entries were removed from the Old E-mail Address field if they were identical to the Current E-mail Address using the following statement.

  UPDATE [tbl_IMAT_PI/PDs] SET [tbl_IMAT_PI/PDs].[E-mail Address] = NULL WHERE [tbl_IMAT_PI/PDs].[E-mail Address]=[tbl_IMAT_PI/PDs].[E-mail Address];

  - The "Current E-mail" column was renamed "E-mail Address" and "E-mail Address" was renamed "Old E-mail Address"
- Once all the changes were QCed, the data were copied to the IMAT PD/PIs list on the IMAT Evaluation SharePoint Site.

  UPDATE [IMAT PI/PDs] LEFT JOIN tbl_IMAT_PI/PDs ON [IMAT PI/PDs].[Profile Person ID]=tbl_IMAT_PI/PDs.[Profile Person ID] SET [IMAT PI/PDs].[E-mail Address] tbl_IMAT_PI/PDs.[E-mail Address], [IMAT PI/PDs].[Old E-mail Address] tbl_IMAT_PI/PDs.[Old E-mail Address];

- There were numerous entries in the PD/PI table with blank External Org IDs. To fill the gaps, the External Org the External Org IDs were pulled from the Applications Data. This table contained a field for both PI ID and Org ID for the submission – In cases where the Org ID in the PD/PI table was blank the number was filled in using the External Org ID from applications by that PI in the IMAT Applications Table.
  - The Org IDs were added to the local copy of the IMAT PD/PIs table using the following statement:
    - *UPDATE [IMAT PI/PDs] LEFT JOIN [tbl_IMAT_PI/PDs] ON [IMAT PI/PDs].[Profile Person ID]=[tbl_IMAT_PI/PDs].[Profile Person ID] SET [IMAT PI/PDs].[External Org ID] = [tbl_IMAT_PI/PDs].[External Org ID]WHERE [IMAT PI/PDs].[External Org ID] IS Null;*
  - Once all the changes were QCed, the data were copied to the IMAT PD/PIs list on the IMAT Evaluation SharePoint Site.
  -

- Upload Applications Table
  - Source Documents: *imat_applications_table.xlsx* provided by Lexical.
  - The IMAT Applications List on SharePoint was populated with the column headers, but no data. This schema was exported to the local MS Access database as a linked table (**IMAT Applications)**
  - The data from the source spreadsheet was uploaded to the local access database (**tbl_IMAT Applications**)
    - The following fields were added to the Applications table:
      - RE_Project_Number – This is a simplified project number (e.g., R21CA081631-01 would become R21CA081631). It was observed that a number of multi-year applications had repeated applications/awards for

each year – removal of the 01, 02 from the end of the project number facilitated an accounting of duplicated applications from the source data.

- RE_PI_ID – This field is a foreign key reference to the unique ID field (primary key) in the PD/PI Table.

- The data fields in the local table were set to match the data fields in the linked table by hand. Once the two schema were matched the data from tbl_IMAT Applications was copied to IMAT Applications using the following statement:
  - *INSERT INTO [IMAT Applications] ([Appl ID], FY, [Application Type], [Activity Code], [Project Number], [Profile Person ID], [Project Title], [External Org ID], [Project Start], [Project End], [RFA/PA Number], Council, Status, [IRG Cluster], [Award Total Cost], [Priority Score], [Criterion 1], [Criterion 2], [Criterion 3], [Criterion 4], [Criterion 5], A1, [Abstract Text], [Commercial Progress], [Criterion X], [Criterion Innovation], RE_PIPD_ID, [RE_Project Number], [RE_PIPD_ID:Profile Person ID]) SELECT [tbl_IMAT Applications].[Appl ID], [tbl_IMAT Applications].FY, [tbl_IMAT Applications].[Application Type], [tbl_IMAT Applications].[Activity Code], [tbl_IMAT Applications].[Project Number], [tbl_IMAT Applications].[Profile Person ID], [tbl_IMAT Applications].[Project Title], [tbl_IMAT Applications].[External Org ID], [tbl_IMAT Applications].[Project Start], [tbl_IMAT Applications].[Project End], [tbl_IMAT Applications].[RFA/PA Number], [tbl_IMAT Applications].Council, [tbl_IMAT Applications].Status, [tbl_IMAT Applications].[IRG Cluster], [tbl_IMAT Applications].[Award Total Cost], [tbl_IMAT Applications].[Priority Score], [tbl_IMAT Applications].[Criterion 1], [tbl_IMAT Applications].[Criterion 2], [tbl_IMAT Applications].[Criterion 3], [tbl_IMAT Applications].[Criterion 4], [tbl_IMAT Applications].[Criterion 5], [tbl_IMAT Applications].A1, [tbl_IMAT Applications].[Abstract Text], [tbl_IMAT Applications].[Commercial Progress], [tbl_IMAT Applications].[Criterion X], [tbl_IMAT Applications].[Criterion Innovation], [tbl_IMAT Applications].RE_PIPD_ID, [tbl_IMAT Applications].[RE_Project Number], [tbl_IMAT Applications].[RE_PIPD_ID:Profile Person ID] FROM [tbl_IMAT Applications];*
    - Note there were a total of 9,307 records in the table; a test set of 5 records was uploaded to SharePoint. Once the test set passed QC, the remaining 9,302 Application records were uploaded in batches of 500 Records.
      - Note: This total includes a number of repeats, however, there were differences in the individual Criterion Scores. Therefore these records could not be hidden. During analysis the RE_Project Number field is used to obtain a unique count of applications.

Update Awards Table

- Source Documents: *imat_awards.xlsx*, *imat_full_project_list.xlsx* from Lexical

- *imat_awards.xlsx* consisted of a single column list of all grant numbers funded as part of the IMAT program. There were numerous repeats; studies that were renewed or extended were repeated in the list (e.g., R21CA081668-01 and R21CA081668-02 represent the same award)
- *imat_full_project_list.xlsx* consisted of a list of grant numbers and included the status of the award (e.g., awarded, withdrawn) and type of application (new, renewal, extension, etc.)
- The list of projects was filtered to only include awarded applications, and to include only a single item of each award. There were a total of 638 Projects once the list was filtered. This list was imported to the local MS Access Database as **dedup_IMAT_Awards**
- A linked copy of the IMAT Evaluation SharePoint Awards list was imported to the Access database as **IMAT Awards**
    - This list was blank; no data fields had been set for this database
    - Most of the relevant information about the awards (PI, Institution, Title, Budget, etc.) was included in the record in IMAT Applications. Therefore the starting schema for IMAT Awards was a copy of the schema for IMAT Applications.
        - The individual criteria scores were removed from the Award schema.
        - The Following columns were added to the Awards Table:
            - *Duration*: This column was calculated in months using the start and end dates of the project
            - *FY15 Targeted Evaluation*: This column was a Yes/No checkbox to denote projects selected for the FY15 Evaluation
            - *Associated Publications*: This column contains a list of Publication PMID numbers that cited the grant as a funding source. (The Process of developing this list is discussed in detail below.)
            - *Publication Count*: This column contained a count of the publications associated with the grant. (The Process of developing this number is discussed in detail below.)
            - *Associated Patents*: This column contains a list of Patent ID numbers that cited the grant as a funding source. (The Process of developing this list is discussed in detail below.)
            - *Patent Count*: This column contained a count of the patents associated with the grant. (The Process of developing this number is discussed in detail below.)
    - To populate the IMAT Awards table with data, Application information was copied for IMAT Applications where the grant number in dedup_IMAT_Awards matched the Project Number in IMAT_Applications: the following statement was used:
        - *UPDATE dedup_IMAT_AWARDS LEFT JOIN [IMAT Applications] ON dedup_IMAT_Awards.[Grant Number]=[IMAT Applications].[Project Number] dedup_IMAT_AWARDS.[Appl ID_orig]=[IMAT Awards].[Appl ID_orig], dedup_IMAT_AWARDS.[Activity Code]=[IMAT Awards].[Activity Code], dedup_IMAT_AWARDS.[Application Type]=[IMAT Awards].[Application Type], dedup_IMAT_AWARDS.[ID: Profile Person ID]=[IMAT Awards].[ID: Profile Person ID], dedup_IMAT_AWARDS.[Project Title]=[IMAT Awards].[Project Title], dedup_IMAT_AWARDS.[Abstract Text]=[IMAT Awards].[Abstract Text],*

dedup_IMAT_AWARDS.[Project Start]=[IMAT Awards].[Project Start], dedup_IMAT_AWARDS.[Project End]=[IMAT Awards].[Project End], dedup_IMAT_AWARDS.[RFA/PA Number]=[IMAT Awards].[RFA/PA Number], dedup_IMAT_AWARDS.Council=[IMAT Awards].Council, dedup_IMAT_AWARDS.Status=[IMAT Awards].Status, dedup_IMAT_AWARDS.A1=[IMAT Awards].A1, dedup_IMAT_AWARDS.FY=[IMAT Awards].FY, dedup_IMAT_AWARDS.[Commercial Progress]=[IMAT Awards].[Commercial Progress], dedup_IMAT_AWARDS.[Priority Score]=[IMAT Awards].[Priority Score], dedup_IMAT_AWARDS.[IRG Cluster]=[IMAT Awards].[IRG Cluster], dedup_IMAT_AWARDS.[Award Total Cost]=[IMAT Awards].[Award Total Cost], dedup_IMAT_AWARDS.RE_PIPD_ID=[IMAT Awards].RE_PIPD_ID, dedup_IMAT_AWARDS.[External Org ID_orig]=[IMAT Awards].[External Org ID_orig], dedup_IMAT_AWARDS. .[Profile Person ID]=[IMAT Awards].[Profile Person ID], dedup_IMAT_AWARDS.[FY15 Targeted Evaluation]=[IMAT Awards].[FY15 Targeted Evaluation], dedup_IMAT_Awards.[RE_Project Number]=[IMAT Applications].[RE_Project Number], dedup_IMAT_Awards.[Abstract Text= [IMAT Applications].[Abstract Text], dedup_IMAT_Awards. [Specific Aims]=[IMAT Applications].[Specific Aims], dedup_IMAT_Awards.[Public Health Relevance]=[IMAT Applications].[Public Health Relevance] WHERE dedup_IMAT_Awards.[Grant Number]=[IMAT Applications].[Project Number];

- Once the data had been QCed in the local IMAT Awards table the information was copied to IMAT Awards on SharePoint. A test set of five records was uploaded to SharePoint. Once the test set passed QC, the remaining awards were uploaded to SharePoint.
- Following upload, it was observed that several columns were improperly displaying as numbers with commas (e.g., 123,456 instead of 123456). This occurred in the Appl_ID, Profile Person ID, and External Org ID fields. This also had the effect of preventing execution of sql queries joining the awards table to other tables (PD/PIs, Institutions) that use these fields as foreign keys. To rectify this, another column was created for each field that calculated the numeric value as text. This rectified both the display issue, as well as the mismatch error when executing queries.
    - The original data field was renamed to indicate that is was the original column while the new column was given the original columns name (e.g., Appl ID became Appl ID_orig and the calculated column became Appl ID).
- During the analysis process additional columns were added to aid in the analysis of the awards:
    - Project_Number: This is a copy of the RE_Project Number field – because that field was a look-up type field, it could not be used in SQL JOIN queries to pull information from IMAT Publications and IMAT Patents.

    - Funding Mechanism: This field categorizes all awards as either R21/R33 or SBIR/STTR awards depending on the activity code of the award.
    - Project_Number_Condense: Field containing the project number of the award without the Activity Code (R21, R33 etc.) portion. This enabled grouping of coupled awards that have the same base project number, but different activity codes.
    - Follow-on Study: Categorizes awards uncoupled, or as the initial or follow-up award in a coupled award pair.
    - Coupled Award: Categorizes awards as either coupled or uncoupled awards.
    - Is Awarded: All awards on this table were categorized as Yes – this field was added to enable filtering of awards vs. application in the Applications/Awards graphs.
    - Year 1 Cost: Year 1 Cost for the award
    - Year 2 Cost: Year 2 Cost for the award
    - Year 3 Cost: Year 3 Cost for the award
    - Year 4 Cost: Year 4 Cost for the award
    - Year 5 Cost: Year 5 Cost for the award
    - Year 6 Cost: Year 6 Cost for the award
    - Year 7 Cost: Year 7 Cost for the award
- Total Cost (All Years): Sum of all years for the award

Obtaining Patent Information

Extracting Project Numbers from Patents

As part of an agreement with the USPTO, Google provides bulk downloads of patents. Each file contains approximately one week's worth of data, and consists of an individual zipped file containing multiple XML- or ASCII-structured patent records. To date, there are approximately 6.1 million individual patent records (1976 - present) available.

Within an individual record, the Federal support statement is demarcated. The Federal support statement is a free-text field that loosely follows convention for citing government support. Examples include:

> `This invention was made with government support under Grant Nos. R21 EY017393 and K12-EY01633305 awarded by the National Institutes of Health. The government has certain rights in the invention.`
>
> `This invention was made with Government support under grant numbers AI112202, AI14784, and AI32834 awarded by the National Institutes of Health. The Government has certain rights in the invention.`
>
> `This application was supported by Grant No. 1R44CA153481-01A1 and Grant No. R01CA140617 awarded by the National Cancer Institute. The U.S. government has certain rights in the invention.`

The main challenge in extracting NIH project numbers from the Federal support statement is related to the variation in form of the project numbers. Ripple Effect's approach to dealing with this variation is divided into three parts, each of which is described in greater detail below:

1. A text normalization step to remove variation in spacing and punctuation.
2. Loose matching of potential project numbers based on regular expressions, and
3. Precise lookup of potential project numbers against awarded projects in IMPAC II.

Text Normalization

The Federal support statement is passed through a text analyzer that replaces punctuation characters with space, separates numeric sequences from character sequences, removes leading zeros, and replaces capital letters with lower case letters. Examples of normalized project numbers are shown below.

Original Text	Normalized Text
`R21 EY017393`	`r 21 ey 17393`
`AI14784`	`ai 14784`
`1R44-CA153481-01A1`	`1 r 44 ca 153481 1 a 1`

Regular Expression Matching

The normalized text is matched against a regular expression that is constructed to match potential sequences of activity code, admin IC, and serial numbers occurring in the Federal support statement. At this stage of matching, the letter 'O' is considered equivalent to the number zero when it is found in the activity code so that 'R01' (letter 'O') matches 'R01' (the number zero).

Precise Lookup

The text normalization and regular expression steps are designed to cast a wide net in the search for potential NIH project numbers and may match character sequences that normalize to apparent, but invalid, NIH project numbers (an example would be a combination of admin IC and serial number that do not correspond to an actual project number). Therefore, the last step is to look up extracted sequences of activity code, admin IC, and serial numbers in IMPAC II to verify that they are valid project numbers. The lookup procedure occurs in two steps:

1. In cases where each of the activity code, admin IC, and serial number are extracted, these three components are used for the IMPAC II lookup (examples 1 and 3).
2. In cases where the inventor did not specify an activity code (example 2), the admin IC and serial number are used to look up all matching activity codes (i.e., AI14784 matches to either R01AI014784 or R37AI014784).

iEdison/ExPORTER

In addition to automatically extracting grant numbers from source patent data, we used patent data available from ExPORTER:

http://exporter.nih.gov/ExPORTER_Catalog.aspx?sid=0&index=3

Patent-to-Patent Citations

The patent records contain a bibliographic section that identifies citations made by a given patent to other patents and journal articles. We extracted patent numbers from the citation section to provide citation links between patents.

The process for identifying citation links from patents to publications is described in a separate "Publication Linking" document.

Patent Class Codes

http://www.ibiblio.org/patents/classes.html

Update Patents Table

- Source Documents: patents.csv
- Patents.csv was imported to the local access database as **tbl_patents**
- Column titles were added to the Patents list to match the headers in patents.csv. This list was linked to the access database as **IMAT Patents**.
    - The following columns were added to the Patents Table:
        - *Associated IMAT Awards*: This column contains a list of Grant numbers associated with the publication. (The Process of developing this list is discussed in detail below.)
        - *Award Count*: This column contained a count of the grants associated with the publication. (The Process of developing this number is discussed in detail below.)

    - *Associated Publications*: This column contains a list of PMID numbers associated with the patents. (The Process of developing this list will be discussed in detail below.)
    - *Publication Count*: This column contained a count of the publications associated with the patent. (The Process of developing this number will be discussed in detail below.)
    - *Pub Year:* This column contains the year only portion of the patent publication date.
    - *Application Year:* This column contains the year only portion of the patent application date.
    - *Patent Class 1:* This contains the text of the first patent class listed form the patent class field.
    - *Patent Class 2:* This contains the text of the second patent class listed form the patent class field.
- The data fields in the local table were set to match the data fields in the linked table by hand. Once the two schema were matched the data from tbl_IMAT_Patents was copied to IMAT Patents using the following statement:
    - *INSERT INTO [IMAT Patents] ([Patent ID], [Patent Title], Abstract, Inventor, [Patent Type], Assignee, [Federal Support], [Related Patents], [Patent Class], [Pub Date], [Application Date]) SELECT tbl_patents.[Patent ID], tbl_patents.[Patent Title], tbl_patents.Abstract, tbl_patents.Inventor, tbl_patents.[Patent Type], tbl_patents.Assignee, tbl_patents.[Federal Support], tbl_patents.[Related Patents], tbl_patents.[Patent Class], tbl_patents.[Pub Date], tbl_patents.[Application Date] FROM tbl_patents*

Publication Methodology

Bibliometrics is the quantitative evaluation of the productivity, impact, and collaboration represented by scientific publications in a specific field. It is a standard means of assessing the outcomes generated by research projects (Moodley et al., 2015). Research publications are widely considered to be an important product of scientific research, in part because they provide a vital link between the creation of new scientific knowledge and its application (Moodley et al., 2015). Rothwell, Lobo, Strumsky, & Muro (2013) have found that scientific publications directly foster scientific knowledge. They cite a recent survey of U.S. inventors who filed patents in the United States, Japan, and Europe, in which 39% of respondents claimed that scientific publications were an “important” or “very important” source of information that contributed directly to their patents.

Bibliometrics can also be used to identify emerging areas. If two or more papers on the same topic appear around the same time, it can be an indication that the subject is an emerging one that may deserve attention (Lawrence, 2003). The publication of research results in a major medical journal can be considered an indicator of the importance that the medical community ascribes to the findings, and hence to its impact (AEA, 2015). Furthermore, an advantage of bibliometric analysis for evaluation is that it is a relatively low-cost and low-burden method compared with other quantitative methods (Moodley et al., 2015).

It is important to note that traditional bibliographic analysis has some recognized inherent limitations that must be mitigated in order to ensure it is an effective indicator of performance. As Thonon et al.

(2015) note, the number of citations does not necessarily correlate with the importance, and the number of citations may be skewed by a few highly cited papers. Glynn, Chin, Kerin, & Sweeney (2010) found that two commonly used measures of the importance of scientific journals (impact factor and Eigenfactor®) do not necessarily serve as an accurate indicator of the quality of the oncology research published in them; their analysis of the literature demonstrated that impactful research is not always published in prestigious journals with high impact factors. Furthermore, as Hirsch (2005) argues, the measurement of the number of times a paper is cited rewards low productivity and penalizes high productivity. Finally, it should be noted that as a quantitative rather than qualitative measure, bibliometric analysis does not attempt to evaluate or interpret the content of the publication or the quality of the research, but rather measures the productivity, impact, and evidence of collaboration of the article itself (Moodley et al., 2015).

In light of these findings, the Institute of Electrical and Electronics Engineers (IEEE) Board of Directors (2013) promulgated three tenets for assessing journals, research proposals, and individuals in engineering, computer science, and information technology. While not directly related to biomedical research, these three tenets are also broadly applicable to the accurate bibliometric analysis of other scientific disciplines, such as that supported by IMAT, and provide useful guidance for bibliographic analysis:

1. A comprehensive and balanced analysis requires the use of several complementary bibliometric indicators, rather than reliance on a single method.
2. Journal-based metrics should not be considered as proxies for the quality of individual papers or authors.[36]
3. Peer review should be considered the primary means of assessing the quality of scientific research and researchers, with bibliometrics providing additional information related to specific areas of research.

Linking Publications to Grants

Citations of IMAT grants by journal articles were obtained from the publicly available version of SPIRES data from ExPORTER:

http://exporter.nih.gov/ExPORTER_Catalog.aspx?sid=3&index=2

A computer program was written to download all of the publication files from ExPORTER and match the project numbers available there with IMAT project numbers. In addition to this data set, we manually linked 35 additional journal articles from a previous IMAT analysis that were not contained in the ExPORTER data set.

Comparison of STPI and Ripple Effect Patent Data Pull

- Ripple Effect found 30 of the 33 patent numbers STPI found. The remaining three did not have a Federal support section.
- STPI found 80 application numbers that did not have a patent number. There were no matches for application numbers identified by STPI, but there were many STPI applications identified by their publication number (those that have a Federal support section).
- Ripple Effect did not find the foreign applications identified by STPI.

[36] See also Glynn, Chin, Kerin, & Sweeney, 2010 in this regard, as discussed above.

Update Publications Table

- Source Documents: publications.csv
- The publications list on the IMAT Evaluation SharePoint was blank. Column titles were added to the list to match the headers in publications.csv. This list was linked to the Access database as **IMAT Publications**.
    - The following columns were added to the Publications Table:
        - *Associated IMAT Awards*: This column contains a list of Grant numbers associated with the publication. (The process of developing this list is discussed in detail below.)
        - *Award Count*: This column contained a count of the grants associated with the publication. (The process of developing this number is discussed in detail below.)
        - *Associated Patents*: This column contains a list of Patent ID numbers associated with the publication. (The process of developing this list is discussed in detail below.)
        - *Patent Count*: This column contained a count of the patents associated with the publication. (The process of developing this number is discussed in detail below.)
        - The data fields in the local table were set to match the data fields in the linked table by hand. Once the two schema were matched the data from tbl_IMAT_publications was copied to IMAT Publications using the following statement:
            - *INSERT INTO [IMAT Publications] ([IMAT Publications].[Pub Title], [IMAT Publications].[PMID], [IMAT Publications].[Authors], [IMAT Publications].[Journal Title], [IMAT Publications].[isoJournalTitle], [IMAT Publications].[Publication Date], [IMAT Publications].[Journal Volume], [IMAT Publications].[Journal Issue], [IMAT Publications].[Journal Country], [IMAT Publications].[issn], [IMAT Publications].[Pages Mesh], [IMAT Publications].[Terms Language], [IMAT Publications].[Last Revision], [IMAT Publications].Mesh Date], [IMAT Publications].[Publication Year], [IMAT Publications].[Impact Factor], [IMAT Publications].[Publish Status], [IMAT Publications].[Total Number of Cities], [IMAT Publications].[DOI], [IMAT Publications].[SCOPUS ID], [IMAT Publications].[SCOPUS URL], [IMAT Publications].[NUM CITATIONS 2003], [IMAT Publications].[NUM CITATIONS 2004], [IMAT Publications].[NUM CITATIONS 2005], [IMAT Publications].[NUM CITATIONS 2006], [IMAT Publications].[NUM CITATIONS 2007], [IMAT Publications].[NUM CITATIONS 2008], [IMAT Publications].[NUM CITATIONS 2009], [IMAT Publications].[NUM CITATIONS 2010], [IMAT Publications].[NUM CITATIONS 2011], [IMAT Publications].[NUM CITATIONS 2012], [IMAT Publications].[NUM CITATIONS 2013], [IMAT Publications].[Total Citations Since 2003], [IMAT Publications].[Public Access Compliance], [IMAT Publications].[PubMed Link]) SELECT [tbl_IMAT_Publications].[Pub Title], [tbl_IMAT_Publications].[PMID],*

[tbl_IMAT_Publications].[Authors], [tbl_IMAT_Publications].[Journal Title], [tbl_IMAT_Publications].[isoJournalTitle], [tbl_IMAT_Publications].[Publication Date], [tbl_IMAT_Publications].[Journal Volume], [tbl_IMAT Publications].[Journal Issue], [tbl_IMAT_Publications].[Journal Country], [tbl_IMAT_Publications].[issn], [tbl_IMAT_Publications].[Pages Mesh], [tbl_IMAT_Publications].[Terms Language], [tbl_IMAT_Publications].[Last Revision], [tbl_IMAT_Publications].Mesh Date], [tbl_IMAT_Publications].[Publication Year], [tbl_IMAT_Publications].[Impact Factor], [tbl_IMAT_Publications].[Publish Status], [tbl_IMAT_Publications].[Total Number of Cities], [tbl_IMAT_Publications].[DOI], [tbl_IMAT_Publications].[SCOPUS ID], [tbl_IMAT_Publications].[SCOPUS URL], [tbl_IMAT_Publications].[NUM CITATIONS 2003], [tbl_IMAT_Publications].[NUM CITATIONS 2004], [tbl_IMAT_Publications].[NUM CITATIONS 2005], [tbl_IMAT_Publications].[NUM CITATIONS 2006], [tbl_IMAT_Publications].[NUM CITATIONS 2007], [tbl_IMAT_Publications].[NUM CITATIONS 2008], [tbl_IMAT_Publications].[NUM CITATIONS 2009], [tbl_IMAT_Publications].[NUM CITATIONS 2010], [tbl_IMAT_Publications].[NUM CITATIONS 2011], [tbl_IMAT_Publications].[NUM CITATIONS 2012], [tbl_IMAT_Publications].[NUM CITATIONS 2013], [tbl_IMAT_Publications].[Total Citations Since 2003], [tbl_IMAT_Publications].[Public Access Compliance], [tbl_IMAT_Publications].[PubMed Link] FROM [tbl_IMAT_Publications];

- Following upload, it was observed that the PMID field was improperly displaying as a number with commas. This was rectified by creating a copy column that calculated the value as text. The original data field was renamed to indicate that is was the original column while the new column was given the original columns name (PMID became PMID_orig and the calculated column became PMID ID).

Linking Publications to Patents

In addition to the direct publication-to-grant citations obtained from ExPORTER, The evaluation team obtained citations by patents of IMAT-supported publications.

For example, R21CA086132 is acknowledged by PMID 11171990 “Origin of nanomechanical cantilever motion generated from biomolecular interactions.” This article is in turn cited by patent US7112452 “Method and sensor for detecting the binding of biomolecules by shear stress measurement.”

Citations contained in patents do not explicitly reference articles by PMID, but by a relatively unstructured citation format. The evaluation team wrote a computer program that

1. extracted citations from patents
2. used a fuzzy string matching algorithm to identify similar titles from a database of Medline articles

An example of such a match is shown below.

US7112452

Wu, G, et al. "Origin of nanomechanical cantilever motion generated from biomolecular interactions." Proc. Natl. Acad. Sci. U.S.A. 98.4 (2001): 1560-4

Medline database contains

Guanghua Wu et al.; Origin of nanomechanical cantilever motion generated from biomolecular interactions; Proc. Natl. Acad. Sci.; Feb. 13, 2001; vol. 98; No. 4; pp. 1560-1564.

The two citations match with a similarity score above a pre-determined threshold, so this article is identified as an example of an IMAT-sponsored publication being cited by a patent.

Incorporating Associated Number of Publications, Patents, and Grants

- Source documents: *publications_to_grants.csv; publications_to_patents.csv, patents_to_grants.csv; patents_to_publications.csv.*
    - Each .csv consisted of two columns that matched the ID numbers of the entities.
    - A single grant could have one or many patents/publications resulting from the funding, or a single patent could utilize information from multiple grants/publications the relationships between these three entities is complex.
- To present the data in SharePoint, a VBA module was built to combine the entities associated with a particular grant/patent/publication into a semi colon delimited string. The Module also generated a count of the entities associated. For example for a particular grant with 5 publications, the module would collapse all 5 PMID numbers into a sting in one column, it would also add a value of "5" to the count column.
    - The Module needed to be run for each type of document/relationship. For each relationship the script had to be modified slightly in order to properly direct it regarding which fields to pull data from, however the basic logic of the script is the same.
        - The basic module used is as follows:

```
Sub Write_Exceptions_To_Table()
Dim db As Database
Dim rsGet As Recordset
Dim rsWrite As Recordset
Dim varPatentID As Variant
Dim varNextPatentID As Variant
Dim strBuild As String
Dim intNumElements As Integer
Set db = CurrentDb()
Set rsGet = db.OpenRecordset("SELECT PatentID, Patent_Title, Abstract, Inventor,
Patent_type, Assignee, Federal_Support, Related_Patents, Patent_Class, Pub_Date,
Application_Date, Grant_Number FROM [Patents_Grants] ORDER BY PatentID;")
Set rsWrite = db.OpenRecordset("Patents_grants2")
With rsGet
 Do While Not .EOF
 varPatentID = ![PatentID]
 .MoveNext
 If Not .EOF Then
 varNextPatentID = ![PatentID]
 Else
 varNextPatentID = "EOF"
 End If
 .MovePrevious
 strBuild = strBuild & ![Grant_Number] & ", "
 intNumElements = intNumElements + 1
```

```
If Not (varPatentID = varNextPatentID) Then
'add record to table
strBuild = Left(strBuild, Len(strBuild) - 1)
With rsWrite
.AddNew
!PatentID = rsGet![PatentID]
!Grant_Number = strBuild
!Grant_Count = intNumElements
.Update
End With
're-initialize variables
strBuild = ""
intNumElements = 0
End If
.MoveNext
Loop
End With
rsGet.Close
rsWrite.Close
Set rsGet = Nothing
Set rsWrite = Nothing
Set db = Nothing
End Sub
```

- The Module was run for each of the following relationships:
  - For Each Award:
    - Grants to Publications: Generated a list of all the PMID numbers associated with the Grant Number.
    - Grants to Patents: Generated a list of all patents associated with the Grant Number.
  - For Each Patent:
    - Patents to Grants: Generated a list of all Grants associated with the Patents.
    - Patents to Publications: Generated a list of all Publications associated with the Patent.
  - For Each Publication:
    - Publications to Grants: Generated a list of all Grants associated with the publication.
    - Publications to Patents: Generated a list of patents associated with the publication.
- Once the strings were built, the data were copied to its corresponding column in IMAT Awards, IMAT Patents, or IMAT Publications.

Appendix H – Evaluation Data Collection Instruments

2015 IMAT Evaluation Web-based Survey

Survey of Technology Development Grants

OMB No.: 0925-XXXX
Expiration Date: xx/xx/20xx

Collection of this information is authorized by The Public Health Service Act, Section 410 (42 USC 285). Rights of participants are protected by The Privacy Act of 1974. Participation is voluntary, and there are no penalties for not participating or withdrawing from the study at any time. The information collected in this study will be kept private to the extent provided by law. Names and other identifiers will not appear in any report of the study. Information provided will be combined for all participants and reported as summaries. You are being contacted by email to complete this survey as part of a full-scale evaluation of the Innovative Molecular Analysis Technologies (IMAT) Program.

Public reporting burden for this collection of information is estimated to average 30 minutes per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. An agency may not conduct or sponsor, and a person is not required to respond to, a collection of information unless it displays a currently valid OMB control number. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden to: NIH, Project Clearance Branch, 6705 Rockledge Drive, MSC 7974, Bethesda, MD 20892-7974, ATTN: PRA (0925-XXXX). Do not return the completed form to this address.

You have been selected as a member of the research community who has previously received a grant award from the National Institutes of Health (NIH) for support of technology development research. This survey is part of a comprehensive evaluation of the Innovative Molecular Analysis Technologies (IMAT) program of the National Cancer Institute (NCI). Your experience and views regarding NIH support for the development of highly innovative technologies to advance biomedical research and clinical care capabilities will directly inform this evaluation and as such, NCI appreciates your willingness to participate.

Thank you for your time and support. Click the Continue button below to begin the survey.

Grant Information

Grant Number:

Institution:

Please confirm that the institution on the grant is correctly listed above. If not, please correct it below.

1. Yes, it is correct
2. No, it should be recorded as: _____

Title of Grant:

Your role on the grant:

Please confirm that your role on the grant is correctly listed above. If not, please correct it below.

1. Yes, it is correct
2. No, it was: _____

What is the trademarked or formally designated name of the technology or methodology for this grant?

Please list below any alternative names or common terms that you or others have used for the specific technology/research described in this grant. Separate names with a semi-colon.

Technology or Methodology Developed Under Grant

What are the intended major uses of the ultimate technology(s) or methodology that resulted, or might still result, from your grant?

Who are the intended users of the ultimate technology(s) or methodology(s) that resulted, or might still result, from your grant?

On a scale of 0 to 10, please rate the riskiness of your proposal at the time of the grant application.

1. 0
2. 1
3. 2
4. 3
5. 4
6. 5
7. 6
8. 7
9. 8
10. 9
11. 10

On a scale of 0 to 10, please rate the potential significance/reward of your research at the time of the grant application.

1. 0
2. 1
3. 2
4. 3
5. 4
6. 5

7. 6
8. 7
9. 8
10. 9
11. 10

Please select the most appropriate categorization of your technology/methodology developed under this grant (Select all that apply).

1. **Small Molecules**: Tools or methods for the development or reformulation of drugs as chemical substances used in the treatment, cure, prevention, or diagnosis (in vivo, imaging agents, etc.) of disease or used to otherwise enhance physical or mental well-being; includes so-called "naturopathic" or naturally-derived substances in alternative care regimes.
2. **Biologics**: Tools or methods that facilitate the development of medicinal products created by biologic processes, such as a vaccine, blood or blood component, allergenic, somatic cell, gene therapy, tissue, recombinant therapeutic protein, or living cells.
3. **Companion Product**: A diagnostic, therapeutic, or device that must be used in combination with another diagnostic, therapeutic, or device type (e.g., companion diagnostic for a specific therapy; a small molecule that activates expression from a gene therapy vector; a device and imaging agent that work together). This does not include "drug cocktails."
4. **Medical Devices**: The development and/or use of instruments or machines, used in the diagnosis of disease or in the cure, mitigation, treatment, or prevention of disease or conditions associated with the deterioration of physiological function (e.g., prostheses); this would also include medical imaging devices and the use of innovative materials to construct new devices.
5. **Research Tools**: The development of new or improved tools, devices, methods, and sensors to enhance laboratory or field studies on humans, animals, or any model system. This includes tools and methods that broaden the research knowledge base and for biomonitoring.
6. **Biotechnology**: Tools or methods that facilitate the use of microorganisms, such as bacteria or yeasts, to perform specific industrial or manufacturing processes.
7. **In Vitro and Ex Vivo Diagnostics**: The use of tools (software, hardware, or combinations) to identify or screen for medical conditions and determine whether specified diseases or disease processes are present in living organisms. Includes the use of these tools for non-clinical screenings and to provide insights in the work of clinicians, providers, manufacturers of equipment, and companies involved in therapies associated with disease.
8. **Healthcare IT**: Approaches and tools derived from information technology that allow for the management of research, educational, and medical information. Includes software, media, educational tools, and digital health.
9. **Other**

Please further specify the type of research tool/method. (Select all that apply.)

1. Cancer modeling (e.g., cell culture, animal models)
2. Drug delivery/targeting/screening
3. High-throughput screening (e.g., genome, transcripts, proteins)
4. Imaging tools or contrast agents
5. Novel biosensors and/or early detection platforms
6. Sample preparation or processing
7. Sample preservation and/or sample quality assessment

8. Other

To which disease(s) or research area(s) does your technology or methodology apply? (Select all that apply.)

1. Aging
2. Alcohol Abuse and Alcoholism
3. Allergy, Autoimmune, and Infectious Diseases
4. Arthritis and Musculoskeletal and Skin Diseases
5. Behavioral and Social Sciences Research
6. Biomedical Imaging and Bioengineering
7. Cancer
8. Cardiovascular Research (Heart, Lung, and Blood)
9. Child Health & Human Development
10. Complementary and Alternative Medicine
11. Deafness and Other Communication Disorders
12. Dental and Craniofacial Research
13. Diabetes and Digestive and Kidney Diseases
14. Dietary Supplements
15. Drug Abuse and Addiction
16. Environmental Health Sciences
17. Eye Disease and Disorders of Vision
18. General Medical Sciences
19. Genetics/Genomics
20. Global Health
21. HIV/AIDS
22. Mental Health
23. Minority Health and Health Disparities
24. Neurological Disorders and Stroke
25. Nursing Research
26. Translational Research
27. Women's Health

Please list any preceding technology(s) or methodology(s) for which your own technology or methodology offered superior performance capabilities. Please list no more than five, separated by a semi-colon.

Did the technology/methodology that you developed under the ${GrantInfo3} award have any relation to an earlier technology/methodology used by you or someone else?

1. Yes, by me
2. Yes, by someone else
3. No

Please indicate the number of individuals (by type) who are, or were, on your research team for this grant.

Note this includes investigators, post-doctoral researchers, and students.
Engineers ____
Clinicians ____
Chemists ____
Biologists ____
Materials Scientists ____
Physicists ____
Molecular Biologists
Biochemists
Biophysicists
Other ____

How would you best categorize the stage of development your technology/methodology was in prior to grant award?

1. Concept only – no reasonable development undertaken
2. Non-clinical technology/methodology in prototype development/testing stage
3. Non-clinical technology/methodology in full development/testing stage
4. Pre-clinical development
5. Commercially available

Did your grant objectives (e.g., aims) formally change over the course of grant period?

1. Yes
2. No

Application Submission Process

The following two questions are related to the original application submission time period.

Did you apply to another NIH award program to support this research idea?

1. Yes
2. No

Would other NIH programs have been a suitable fit for your NIH application?

1. Yes, at least one other program may have worked for me
2. Yes, several other programs may have worked for me
3. No, this program was the only one that was appropriate for this research idea

Interactions with NCI, NIH, and Other Institutions

Prior to grant award, were meetings/discussions with NIH grant representatives (e.g., program officers, grant staff) productive and useful in developing the research/technology for your grant?

1. 1. Yes
2. Somewhat
3. No
4. I did not participate in meetings prior to grant award

During the grant period, were interactions with NIH program officers and grant staff productive and useful in developing the research/technology?

1. Yes
2. Somewhat
3. No
4. I had no interactions with NIH staff during the grant period

[If NOT no interactions] Please elaborate on the utility of these interactions in developing the research/technology.

Did your attendance at grant meetings/discussions help catalyze new projects with collaborators beyond the key personnel on the grant-supported technology?

1. Yes
2. No
3. I did not attend grant meetings.

Grant Outcomes

How would you best categorize the stage of development for your technology/methodology at the conclusion of the grant?

1. Concept only – no reasonable development undertaken
2. Non-clinical technology/methodology in prototype development/testing stage
3. Non-clinical technology/methodology in full development/testing stage
4. Pre-clinical development
5. Commercially available
6. Discontinued

How would you best categorize the stage of development for your technology/methodology today?

Concept only – no reasonable development undertaken
Non-clinical technology/methodology in prototype development/testing stage
Non-clinical technology /methodology in full development/testing stage
Pre-clinical development
Commercially available
Discontinued
Don't know

Is this technology/methodology ready for market/dissemination?

1. Yes
2. No

Did you achieve the primary objectives of your funded grant?

1. Yes, all
2. Yes, most
3. Yes, some

4. No

[If NOT yes, all] Despite not achieving all of your grant objectives, please briefly describe the importance of the results you were able to achieve.

Has your research led to a marketable technology or a widely accepted methodology?

Yes

No

This research was not intended to lead to a marketable technology or a widely accepted methodology

[If no] Why not? (Select top two)

Research results were not as expected

Required more funds

Did not have the support of my institution

The need for my technology became obsolete before it could get to the market stage

Collaborators did not deliver expected results

Did not have the knowledge and/or resources to get to market stage

Too many steps (i.e., too much regulation and paperwork) required to get to market stage

Other please specify:

Application and Dissemination of Your Technology

For the research/technology funded through the ${GrantInfo3} grant, have you…

	Yes	No
Presented at scientific meetings or conferences	❑	❑
Presented to clinical audiences	❑	❑
Given seminars	❑	❑
Written papers and publications	❑	❑

Are you aware of any additional technologies or methods that have been developed as a result/extension of the results of your grant?

1. Yes
2. No

[If yes] Please list the additional technologies/methods that have been developed as a result/extension of the technology you developed from the results of your grant.

Have others involved with your grants, including any of your students, junior investigators, or colleagues, taken the initial research/technology and moved it forward without your involvement?

1. Yes
2. No

[If yes] Who has taken the initial research/technology and moved it forward without your involvement? Please specify name, department (if applicable), and institution/organization.

[If yes] Have any new technologies or methods been developed as a result?

1. No
2. I do not know
3. Yes, please specify: _____

How would you categorize the status of your research/technology related to:

	Not applicable	Not planned	Planned	Submitted/ Initiated	Approved/ Completed	Rejected
Clinical trials	❑	❑	❑	❑	❑	❑
Licenses	❑	❑	❑	❑	❑	❑
Patents	❑	❑	❑	❑	❑	❑
FDA approval	❑	❑	❑	❑	❑	❑
International approval	❑	❑	❑	❑	❑	❑

How helpful was your [the awardee institution] in navigating and supporting the patent application and/or technology transfer process?

Very helpful
Helpful
Somewhat helpful
Not helpful
Not applicable – I did not engage in the patent application or technology transfer process for this technology/methodology

Did the research/technology funded by this grant result in the accomplishment or attainment of any of the following?

	Yes	No	N/A
Strategic partnerships	❑	❑	❑
Spin-off companies	❑	❑	❑
Public offering	❑	❑	❑
Merger or acquisition of awardee	❑	❑	❑

Has the technology/method already been adopted by any segments of a user community (e.g., clinical, research)?

1. Yes
2. No

[If yes] Please describe the user community segments and settings of use.

How much of an impact would you say this ${GrantInfo3} grant had in the following areas…

	No Impact	Little Impact	Moderate Impact	Great Impact	N/A (Not a goal of this technology)
Advancement of ability to diagnose	❑	❑	❑	❑	❑
Advancement of ability to treat	❑	❑	❑	❑	❑
Improve quality of biospecimens used in clinical management	❑	❑	❑	❑	❑
Improve utility of biospecimens used in research	❑	❑	❑	❑	❑
Improve standards/methods for conducting cancer research	❑	❑	❑	❑	❑

Funding

Please select the approximate amount of funding obtained for this research/technology prior to your grant award.

No funding
Less than $50,000
$50,000 - $99,999
$100,000 - $499,000
$500,000 - $999,000
$1,000,000 - $4,999,000
$5,000,000 or greater

During or after the grant award period, is/was there other funding support you applied for or received related to use or development of this research/technology?

I received other funding
I applied for other funding but did not receive it
I did not apply for other funding support for this research/technology during the grant period

[If yes] What was the primary purpose of the additional funding?

1. Further development of the research/technology for measurement or technical capabilities
2. Application of the technology to a novel hypothesis

[If yes, received] Who was the source of this funding? (Select all that apply)

NIH
NSF
DOD
NIST
Private
Other, please specify:

[If yes] What is/was the amount of funding obtained for this research/technology during the grant period (excluding this NIH grant award)?

Less than $50,000
$50,000 - $99,999
$100,000 - $499,000
$500,000 - $999,000
$1,000,000 - $4,999,000
$5,000,000 or greater

[If yes] Did/does the technology/method you developed on the ${GrantInfo3} grant play a major role in formulating the proposal for this other funding?

1. Yes
2. No

Other

Please enter any additional comments you may have related to technology/methodology development, application, and post-award processes at NIH, interactions with NIH, or funding.

Please enter any additional comments you may have related to areas not covered in this survey.

Thank you for your time and input. If you have any questions, feel free to contact Tony Dickherber, IMAT Program Director at 301-547-9980 or by email at dickherberaj@mail.nih.gov.

Successful IMAT Awardees Interview Protocol

OMB No.: 0925-XXXX
Expiration Date: xx/xx/20xx

Collection of this information is authorized by The Public Health Service Act, Section 410 (42 USC 285). Rights of participants are protected by The Privacy Act of 1974. Participation is voluntary, and there are no penalties for not participating or withdrawing from the study at any time. The information collected in this study will be kept private to the extent provided by law. Names and other identifiers will not appear in any report of the study. Information provided will be combined for all participants and reported as summaries. You are being contacted by telephone to complete this interview as part of a full-scale evaluation of the IMAT Program. Public reporting burden for this collection of information is estimated to average 60 minutes per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. **An agency may not conduct or sponsor, and a person is not required to respond to, a collection of information unless it displays a currently valid OMB control number.** Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden to: NIH, Project Clearance Branch, 6705 Rockledge Drive, MSC 7974, Bethesda, MD 20892-7974, ATTN: PRA (0925-XXXX). Do not return the completed form to this address.

My name is _____, and I'm a member of the project team working with the National Cancer Institute (NCI) to evaluate the Innovative Molecular Analysis Technologies (IMAT) Program. NCI is conducting a full-scale evaluation of the IMAT Program. I work for _____, a research and evaluation firm in _____, charged with the task of conducting this evaluation. We greatly appreciate your willingness to answer a few questions about the IMAT Program and the technology funded by the IMAT award.

We realize that your time is valuable, so let's get started.

Name [Prepopulate]: Click here to enter text.

Project Title [Prepopulate]: Click here to enter text.

Grant Number [Prepopulate]: Click here to enter text.

Role on the Grant: Click here to enter text.

Current Position Title: Click here to enter text.

Your Technology Prior to Grant Award

The first few questions are intended to help us understand the origins of your technology and relationship with other existing technologies.

How was the idea for this technology generated? (e.g., was it part of any of your earlier grants?)

Click here to enter text.

How did the technology/research you proposed relate to earlier technologies?

Click here to enter text.

Please describe the advantages of this technology/research compared to existing technologies.

Click here to enter text.

[When you applied for the grant] What did you envision as the eventual outcome of this technology (e.g., how it could be used)?

- Click here to enter text.

Grant Application Process

The next few questions are related to the grant application process.

Describe your experience framing your idea into the context, themes, and structure of the IMAT program. Was the process easy or challenging?

Click here to enter text.

Would you have pursued development of this particular technology without IMAT funding?

☐ Yes ☐ No

[If yes] What mechanisms or funding sources would you have pursued/used?

Click here to enter text.

[If R21 and/or R33**] Did/would you prefer the coupled application process to the current uncoupled application process? Why or Why not?**

Click here to enter text.

Please provide any thoughts on your experience in submitting your application to the IMAT program related to clarity of the solicitation.

Click here to enter text.

Please provide any thoughts on your experience in submitting your application to the IMAT program related to the quality of the review process.

Click here to enter text.

Please provide any thoughts on your experience in submitting your application to the IMAT program related to appropriateness of the IMAT program structure and your research goals.

Click here to enter text.

Your Technology During Grant Award

The next few questions are related to the technology/research you developed during the grant period.

Please describe your technology in terms of the novel platforms and chemical methodologies you developed (e.g., what was the new measurement capability that you introduced and what were the new components you developed to make it possible) during the grant period.

Click here to enter text.

Please describe how you advanced the research/technology from the start of the grant to the end of the grant (e.g., did you make specific discoveries that accelerated progress on your project aims?).

Click here to enter text.

How did the research environment at your organization or institution (e.g., institutional support, other related research activities) impact the development of your technology <u>during the grant</u>?

Click here to enter text.

Interactions

The next few questions are related to interactions with other researchers outside your organization or department.

Are there departments or centers at your organization?

☐ Yes ☐ No

If so, during the grant period, do/did you use your technology to pursue new research with other departments or centers?

☐ Yes ☐ No

[If so] With whom? [specify name, department, current institution]

- Click here to enter text.

Have you, or did you, collaborate with other organizations outside your current organization to advance the technology during the grant?

- ☐ Yes ☐ No

[If so] With whom? [specify name, department, current institution]

- Click here to enter text.

[If so] Did these collaborative relationships exist before the IMAT grant?

- ☐ Yes
- ☐ No
- ☐ Some, but not all

Please describe up to three (of your most useful collaborative relationships in terms of advancing your technology.

- Click here to enter text.

How were these collaborative relationships initiated?

- Click here to enter text.

Do any of your collaborations include colleagues from other disciplines?

- ☐ Yes ☐ No

[If yes] Please specify the relevant disciplines:

- Click here to enter text.

The annual IMAT PI meeting is intended to be a forum to talk with colleagues and NIH staff to help advance your work and technology. Did you attend the annual PI meeting during your grant period?

☐ Yes ☐ No

[If yes] What would you recommend for making the annual PI meeting more useful or productive?

Click here to enter text.

Application and Dissemination of the Research/Technology During and After Award

These questions are intended to help us identify ways in which your technology is being applied or disseminated.

Did you achieve all of the aims specified in your IMAT grant?

- ☐ Yes ☐ No

[If not] What were the challenges you experienced?
Click here to enter text.

Would technical assistance have been useful to you?
Click here to enter text.

Could you describe some ways in which you have been able to apply your research/technology since grant award?
Click here to enter text.

Are you aware of an impact that your activities have had on other researchers in the field?

- ☐ Yes ☐ No

[If so] Please describe.
Click here to enter text.

Other

There are three broad and concluding questions left for you.

How could NCI further assist investigators in developing or disseminating their research/technologies?
Click here to enter text.

Do you have any additional comments or concerns related to the IMAT program that we did not cover today? [If so] Please explain.
Click here to enter text.

Do you have any questions or concerns related to this interview or the evaluation of the IMAT program?
Click here to enter text.

Thank you for the time and input today.

Appendix I – Institutions and Organizations with IMAT Awards

The following list represents the organizations and institutions that have been recipients of IMAT awards since 1998, sorted in descending order by number of grant awards.

Institution Name	Number of Grants	Number of Publications	Average Impact Factor	Number of Patent Applications	Number of Patent Awards
YALE UNIVERSITY	17	27	5.58	2	0
DANA-FARBER CANCER INST	16	100	13.74	1	1
UNIVERSITY OF NORTH CAROLINA CHAPEL HILL	13	22	6.47	3	0
JOHNS HOPKINS UNIVERSITY	12	46	6.55	11	2
UNIVERSITY OF CALIFORNIA SAN DIEGO	12	78	7.90	3	2
DUKE UNIVERSITY	11	12	7.28	3	3
ALBERT EINSTEIN COLLEGE OF MEDICINE	10	30	6.33	4	1
HARVARD MEDICAL SCHOOL	10	7	10.11	6	2
STANFORD UNIVERSITY	10	52	9.60	2	0
UNIVERSITY OF WASHINGTON	10	112	8.72	4	0
MASSACHUSETTS INSTITUTE OF TECHNOLOGY	9	29	5.32	5	3
UNIVERSITY OF WISCONSIN-MADISON	8	58	5.80	11	0
PURDUE UNIVERSITY WEST LAFAYETTE	7	12	5.22	1	0
UNIVERSITY OF CALIFORNIA AT DAVIS	7	62	4.72	7	4
UNIVERSITY OF MICHIGAN	7	47	6.80	0	0
UNIVERSITY OF SOUTHERN CALIFORNIA	7	38	4.87	3	1
ECHELON BIOSCIENCES, INC.	6	2	2.42	4	2
IQUUM, INC.	6	0	0.00	0	0
UNIVERSITY OF CALIFORNIA LOS ANGELES	6	36	8.29	2	0
VIRGINIA POLYTECHNIC INST AND ST UNIV	6	15	4.54	0	0
WISTAR INSTITUTE	6	7	6.81	0	0
BATTELLE PACIFIC NORTHWEST LABORATORIES	5	13	5.35	0	0

Institution Name	Number of Grants	Number of Publications	Average Impact Factor	Number of Patent Applications	Number of Patent Awards
GEORGE MASON UNIVERSITY	5	48	10.84	1	0
HARVARD UNIVERSITY	5	22	7.86	3	8
METHODIST HOSPITAL RESEARCH INSTITUTE	5	10	6.28	0	0
NORTHWESTERN UNIVERSITY	5	20	5.26	0	0
OHIO STATE UNIVERSITY	5	35	3.38	0	1
ONE CELL SYSTEMS, INC	5	0	0.00	1	0
PROGNOSYS BIOSCIENCES, INC.	5	0	0.00	7	5
UNIVERSITY OF CALIFORNIA-IRVINE	5	16	7.18	4	0
UNIVERSITY OF CHICAGO	5	31	6.55	3	1
UNIVERSITY OF CONNECTICUT SCHOOL OF MEDICINE/DENTISTRY	5	7	5.44	0	0
UNIVERSITY OF NEW MEXICO	5	4	2.77	1	0
UNIVERSITY OF PITTSBURGH AT PITTSBURGH	5	35	7.69	3	0
UNIVERSITY OF TEXAS MD ANDERSON CANCER CENTER	5	56	6.81	2	1
VANDERBILT UNIVERSITY	5	41	5.97	2	1
AMERICAN REGISTRY OF PATHOLOGY, INC.	4	16	3.48	1	1
CELL SIGNALING TECHNOLOGY, INC.	4	4	14.49	2	0
EMORY UNIVERSITY	4	0	0.00	1	0
FRED HUTCHINSON CANCER RESEARCH CENTER	4	4	5.99	0	0
IOWA STATE UNIVERSITY	4	2	4.30	0	0
MAYO CLINIC ROCHESTER	4	36	4.60	0	0
SCRIPPS RESEARCH INSTITUTE	4	16	12.22	0	0
THOMAS JEFFERSON UNIVERSITY	4	2	0.00	2	0
TUFTS UNIVERSITY BOSTON	4	1	0.00	5	1
UNIVERSITY OF ILLINOIS URBANA-CHAMPAIGN	4	20	4.48	4	0
UNIVERSITY OF PENNSYLVANIA	4	33	6.05	1	0

Institution Name	Number of Grants	Number of Publications	Average Impact Factor	Number of Patent Applications	Number of Patent Awards
VAN ANDEL RESEARCH INSTITUTE	4	20	5.24	1	0
AMBERGEN, INC	3	2	0.00	0	0
ARIZONA STATE UNIVERSITY-TEMPE CAMPUS	3	10	6.10	0	0
BIOPROXIMITY, LLC	3	0	0.00	3	0
BOSTON UNIVERSITY (CHARLES RIVER CAMPUS)	3	1	4.00	0	0
BROOKHAVEN SCIENCE ASSOC-BROOKHAVEN LAB	3	2	2.87	0	0
CAMBRIDGE RESEARCH AND INSTRUMENTATION	3	7	3.58	1	0
CITY OF HOPE/BECKMAN RESEARCH INSTITUTE	3	6	4.34	0	0
CLEVELAND CLINIC LERNER COM-CWRU	3	9	4.32	0	0
CLEVELAND STATE UNIVERSITY	3	0	0.00	4	0
COLUMBIA UNIVERSITY HEALTH SCIENCES	3	12	6.67	1	0
GEORGIA INSTITUTE OF TECHNOLOGY	3	5	6.39	0	0
ICAHN SCHOOL OF MEDICINE AT MOUNT SINAI	3	1	10.74	0	0
INSTITUTE FOR SYSTEMS BIOLOGY	3	20	5.47	10	8
MASSACHUSETTS GENERAL HOSPITAL	3	45	5.88	0	0
MAXWELL SENSORS, INC.	3	0	0.00	0	0
MEDICAL UNIVERSITY OF SOUTH CAROLINA	3	0	0.00	0	1
ONCQUEST INFORMATION SCIENCES LABS	3	0	0.00	0	0
ORDWAY RESEARCH INSTITUTE, INC.	3	8	5.90	0	0
PHYLONIX PHARMACEUTICALS, INC.	3	1	1.01	0	0
ROCKEFELLER UNIVERSITY	3	33	9.31	3	3
SCI-TEC, INC.	3	4	2.89	1	0

Institution Name	Number of Grants	Number of Publications	Average Impact Factor	Number of Patent Applications	Number of Patent Awards
SLOAN-KETTERING INST CANCER RESEARCH	3	2	7.58	0	1
SRI INTERNATIONAL	3	4	4.58	0	0
SYNTRIX BIOSYSTEMS, INC.	3	3	3.56	2	0
UNIVERSITY OF ARIZONA	3	8	5.80	1	1
UNIVERSITY OF TEXAS HEALTH SCIENCE CENTER HOUSTON	3	23	6.45	2	0
UNIVERSITY OF TORONTO	3	2	26.31	0	0
UNIVERSITY OF WYOMING	3	0	0.00	0	0
UTAH SOUTHWESTERN MEDICAL CENTER	3	17	5.38	3	1
VITATEX, INC.	3	8	3.90	1	0
VOXVILL, LLC	3	0	0.00	0	0
WAKE FOREST UNIVERSITY HEALTH SCIENCES	3	32	5.29	0	0
ACTIVX BIOSCIENCES, INC.	2	0	0.00	0	0
ALBERT EINSTEIN MEDICAL CENTER	2	0	0.00	0	0
ALLEGHENY-SINGER RESEARCH INSTITUTE	2	0	0.00	0	0
ALTHEA TECHNOLOGIES, INC.	2	0	0.00	3	1
AMBION DIAGNOSTICS, INC.	2	3	4.10	1	1
ARCHEMIX CORPORATION	2	0	0.00	0	0
BAYLOR COLLEGE OF MEDICINE	2	5	6.38	0	0
BIOLINX, LLC	2	0	0.00	0	0
BIONANOMATRIX, INC.	2	0	0.00	2	0
BITTECH, INC.	2	2	8.29	2	0
BRANDEIS UNIVERSITY	2	0	0.00	0	0
BRIGHAM AND WOMEN'S HOSPITAL	2	4	11.41	1	0
CARNEGIE-MELLON UNIVERSITY	2	19	4.82	0	0
CASE WESTERN RESERVE UNIVERSITY	2	10	8.85	0	0
CCC DIAGNOSTICS, LLC	2	0	0.00	1	0

Institution Name	Number of Grants	Number of Publications	Average Impact Factor	Number of Patent Applications	Number of Patent Awards
CEDARS-SINAI MEDICAL CENTER	2	0	0.00	0	0
CELLASIC CORPORATION	2	2	2.22	0	0
COLD SPRING HARBOR LABORATORY	2	7	10.34	2	0
CORNELL UNIVERSITY	2	10	4.70	0	0
DREXEL UNIVERSITY COLLEGE OF MEDICINE	2	0	0.00	4	2
ENGINEERING ARTS, LLC	2	0	0.00	0	0
ENO RIVER LABS, LLC	2	30	4.32	0	1
EPIGENX PHARMACEUTICALS	2	0	0.00	0	0
EXPRESSION PATHOLOGY, INC.	2	2	5.11	0	0
FIRST LIGHT BIOSCIENCES, INC.	2	0	0.00	0	0
FLUORRX, INC.	2	0	0.00	1	0
GEORGETOWN UNIVERSITY	2	8	11.63	0	0
GEORGIA REGENTS UNIVERSITY	2	18	4.81	0	0
GOODRICH CORPORATION	2	0	0.00	0	0
H. LEE MOFFITT CANCER CENTER & RESEARCH INSTITITUE	2	0	0.00	0	0
IC BIOSYSTEMS	2	0	0.00	1	3
JACKSON LABORATORY	2	0	0.00	0	0
LUDWIG INSTITUTE FOR CANCER RESEARCH LTD	2	7	20.51	0	0
MEDICAL DISCOVERY PARTNERS, LLC.	2	0	0.00	3	3
MICRONICS, INC.	2	2	3.59	2	3
MULTICOLOR SYSTEMS	2	0	0.00	0	0
NORTHEASTERN UNIVERSITY	2	0	0.00	0	1
OKLAHOMA BIOLABS, INC.	2	0	0.00	1	0
PLATYPUS TECHNOLOGIES, LLC	2	1	3.53	0	0
PRINCETON UNIVERSITY	2	6	15.54	0	0
PROTEIN METRICS, INC.	2	0	0.00	0	0

Institution Name	Number of Grants	Number of Publications	Average Impact Factor	Number of Patent Applications	Number of Patent Awards
PROTEOGENOMICS RESEARCH INSTIT/SYS/ MED	2	0	0.00	4	0
PROTEOVISTA, LLC	2	0	0.00	0	0
PUBLIC HEALTH RESEARCH INSTITUTE	2	0	0.00	0	0
ROSWELL PARK CANCER INSTITUTE CORP	2	6	4.20	1	0
SAINT LOUIS UNIVERSITY	2	3	4.42	5	4
SOMAGENE, INC.	2	0	0.00	0	0
ST. LUKE'S-ROOSEVELT INST FOR HEALTH SCIENCES	2	2	1.13	1	1
TRANSLATIONAL GENOMICS RESEARCH INST	2	1	3.73	0	0
TREVIGEN, INC.	2	0	0.00	0	0
UNIVERSITY OF ARKANSAS FOR MEDIDICAL SCIENCES	2	36	11.43	16	11
UNIVERSITY OF MARYLAND, COLLEGE PARK	2	8	5.76	0	0
UNIVERSITY OF MASSACHUSETTS MEDICAL SCHOOL WORCESTER	2	15	3.16	1	1
UNIVERSITY OF CALIFORNIA-LOS ALAMOS NATIONAL LAB	2	0	0.00	0	0
UNIVERSITY OF CALIFORNIA BERKELEY	2	3	8.91	6	2
UNIVERSITY OF CALIFORNIA, MERCED	2	0	0.00	0	0
UNIVERSITY OF COLORADO	2	8	4.86	0	0
UNIVERSITY OF COLORADO DENVER	2	4	5.38	1	0
UNIVERSITY OF KENTUCKY	2	0	0.00	0	0
UNIVERSITY OF MARYLAND BALT COUNTY CAMPUS	2	4	7.24	0	0
UNIVERSITY OF NEW MEXICO HEALTH SCIENCES CTR	2	0	0.00	4	1
UNIVERSITY OF SOUTH FLORIDA	2	0	0.00	0	0
UNIVERSITY OF TEXAS DALLAS	2	4	2.39	0	0

Institution Name	Number of Grants	Number of Publications	Average Impact Factor	Number of Patent Applications	Number of Patent Awards
UNIVERSITY OF TEXAS HEALTH SCIENCE CENTER	2	1	15.28	0	0
UNKNOWN	2	0	0.00	0	0
VACCINEX, INC.	2	0	0.00	0	0
WADSWORTH CENTER	2	0	0.00	0	0
WASHINGTON STATE UNIVERSITY	2	0	0.00	0	0
WASHINGTON UNIVERSITY	2	3	4.43	0	0
WAYNE STATE UNIVERSITY	2	1	2.42	0	0
WEILL MEDICAL COLL OF CORNELL UNIV	2	6	7.24	0	0
WHITEHEAD INSTITUTE FOR BIOMEDICAL RES	2	0	0.00	0	0
ABREOS BIOSCIENCES, INC.	1	0	0.00	0	0
ACME BIOSYSTEMS, LLC	1	0	0.00	0	0
ADHEREN, INC.	1	0	0.00	0	0
AFFYMETRIX, INC.	1	0	0.00	0	0
ALEXZA MOLECULAR DELIVERY, INC.	1	0	0.00	1	0
ALLELE BIOTECHNOLOGY AND PHARMACEUTICALS	1	0	0.00	0	0
AMBION, INC.	1	0	0.00	0	0
AMPHORA DISCOVERY	1	0	0.00	0	0
ANASAZI BIOMEDICAL RESEARCH, INC.	1	4	4.28	0	0
ARBOR VITA CORPORATION	1	1	4.22	0	0
ATACTIC TECHNOLOGIES, INC.	1	0	0.00	0	0
BAEBIES, INC.	1	0	0.00	0	0
BETH ISRAEL DEACONESS MEDICAL CENTER	1	6	3.65	0	0
BG MEDICINE, INC.	1	0	0.00	0	0
BIO-QUICK CORPORATION	1	0	0.00	0	0
BIOFIRE DIAGNOSTICS, INC.	1	0	0.00	0	0
BIOO SCIENTIFIC CORPORATION	1	0	0.00	0	0

Institution Name	Number of Grants	Number of Publications	Average Impact Factor	Number of Patent Applications	Number of Patent Awards
BIOSPECIMEN PROCUREMENT SOLUTIONS, INC.	1	0	0.00	0	0
BORON BIOLOGICALS, INC.	1	0	0.00	0	0
BOSTON COLLEGE	1	5	12.00	1	0
BOSTON MEDICAL CENTER	1	1	0.00	0	0
BROAD INSTITUTE, INC.	1	0	0.00	0	0
CALIBRANT BIOSYSTEMS, INC.	1	33	4.70	0	0
CAROLYN HENKENS RESEARCH FOUNDATION	1	0	0.00	0	0
CELLECTA, INC.	1	1	4.09	0	0
CELLECTGEN, LLC	1	0	0.00	0	0
CEPHEID	1	2	5.57	0	0
CHARLES STARK DRAPER LABORATORY	1	12	4.69	0	0
CHILDREN'S HOSPITAL CORPORATION	1	0	0.00	0	0
CIRCE BIOMEDICAL, INC.	1	0	0.00	0	0
CLEVELAND BIOLABS, INC.	1	0	0.00	0	0
CODONCODE CORPORATION	1	0	0.00	0	0
COLORADO STATE UNIVERSITY	1	1	0.81	0	0
COLUMBUS NANOWORKS, INC.	1	0	0.00	0	0
CONTROLLED PROCESS TECHNOLOGIES, LLC	1	0	0.00	0	0
CREATV MICROTECH, INC.	1	0	0.00	0	0
CYBERGENETICS CORPORATION	1	0	0.00	0	0
CYVERA CORPORATION	1	0	0.00	0	0
DATA DESCRIPTION, INC.	1	0	0.00	0	0
DELTANU, LLC	1	0	0.00	0	0
EMPIRE GENOMICS. LLC	1	0	0.00	0	0
FASGEN, INC.	1	0	0.00	0	0
GENACO BIOMEDICAL PRODUCTS, INC.	1	0	0.00	0	0
GENEFLUIDICS, INC.	1	0	0.00	0	0

Institution Name	Number of Grants	Number of Publications	Average Impact Factor	Number of Patent Applications	Number of Patent Awards
GENENCOR INTERNATIONAL, INC.	1	0	0.00	0	0
GENEOHM SCIENCES, INC.	1	0	0.00	0	0
GENEPRISM, INC.	1	0	0.00	0	0
GENETICA, INC.	1	0	0.00	0	0
GENMETRIX, LLC	1	0	0.00	0	0
GENOME INSTITUTE OF SINGAPORE	1	0	0.00	0	0
GEORGE WASHINGTON UNIVERSITY	1	0	0.00	0	0
HADASSAH-HEBREW UNIVERSITY MEDICAL CTR	1	3	2.59	0	0
HARVARD SCHOOL OF PUBLIC HEALTH	1	0	0.00	0	0
HEMATOLOGICS, INC.	1	0	0.00	0	0
ILLINOIS FOCUSED BIO-TECHNICAL RESEARCH/INST	1	0	0.00	2	2
IMMUNICON CORPORATION	1	0	0.00	0	0
IMMUNOCHEMISTRY TECHNOLOGIES, LLC	1	0	0.00	0	0
INGENUITY SYSTEMS, INC.	1	0	0.00	0	0
INSTITUTE FOR HEPATITIS & VIRUS RESEARCH	1	0	0.00	0	0
INTERGEN COMPANY	1	0	0.00	0	0
INTRINSIC BIOPROBES, INC.	1	10	5.86	3	2
INTRONN, INC.	1	0	0.00	0	0
IONIAN TECHNOLOGIES, INC.	1	0	0.00	0	0
IVS TECHNOLOGIES, LLC	1	0	0.00	0	0
JOHNS HOPKINS HEALTH SYSTEM	1	0	0.00	0	0
KENT STATE UNIVERSITY AT KENT	1	4	4.25	0	0
LCM TECHNOLOGIES, INC.	1	0	0.00	0	0
LEADSCOPE, INC.	1	0	0.00	0	0
LIFESENSORS, INC.	1	1	0.00	0	0
LINGVITAE AS	1	0	0.00	0	0
LSU HEALTH SCIENCES CENTER	1	0	0.00	0	0

Institution Name	Number of Grants	Number of Publications	Average Impact Factor	Number of Patent Applications	Number of Patent Awards
MACRO SCIENCE SOLUTIONS, LLC	1	0	0.00	0	0
MCGILL UNIVERSITY HEALTH CTR RESEARCH INST	1	0	0.00	1	1
MERRIMACK PHARMACEUTICALS, INC.	1	0	0.00	0	0
MESO SCALE DIAGNOSTICS, LLC	1	0	0.00	0	0
MICROCOSM, INC.	1	0	0.00	0	0
MINERVA BIOTECHNOLOGIES CORPORATION	1	0	0.00	0	0
MIRARI BIOSCIENCES, INC.	1	0	0.00	0	0
MIRNA THERAPEUTICS, INC.	1	0	0.00	2	0
MOLECULAR KINETICS, INC.	1	3	4.30	0	0
MOLECULAR PROBES, INC.	1	1	5.48	0	0
MOLECULAR SCIENCES INSTITUTE	1	0	0.00	0	0
MOLECULAR STAGING, INC.	1	0	0.00	0	0
NANOCELLECT BIOMEDICAL, INC.	1	0	0.00	0	0
NANOMEDICA, INC.	1	13	3.73	0	0
NEOCLONE BIOTECHNOLOGY INTERNATIONAL	1	0	0.00	0	0
NERX BIOSCIENCES, INC.	1	0	0.00	0	0
NEW YORK UNIVERSITY	1	0	0.00	1	0
NEWTON SCIENTIFIC, INC.	1	4	4.87	0	0
NIMBLEGEN SYSTEMS, INC.	1	2	20.03	0	0
NORTH CAROLINA STATE UNIVERSITY RALEIGH	1	16	4.12	0	0
NORTH DAKOTA STATE UNIVERSITY	1	7	4.84	0	0
NORTHWESTERN UNIVERSITY AT CHICAGO	1	3	4.27	1	1
ONCOCELLMDX, INC.	1	0	0.00	0	0
OREGON HEALTH & SCIENCE UNIVERSITY	1	0	0.00	0	0
PALO ALTO VETERAN INSTITUTE FOR RESEARCH	1	0	0.00	0	0

Institution Name	Number of Grants	Number of Publications	Average Impact Factor	Number of Patent Applications	Number of Patent Awards
PENNSYLVANIA STATE UNIVERSITY	1	13	6.74	0	1
PERFUSION TECHNOLOGY, LLC.	1	0	0.00	0	0
PERSCITUS BIOSCIENCES, LLC	1	0	0.00	0	0
PLASMA PROTEOME INSTITUTE	1	0	0.00	0	20
POTOMAC AFFINITY PROTEINS, LLC	1	0	0.00	0	0
PRIMERADX, INC.	1	1	0.00	0	0
PROBE BIOSCIENCES, LLC	1	0	0.00	0	0
RADIATION MONITORING DEVICES, INC.	1	0	0.00	0	0
RAINDANCE TECHNOLOGIES, INC.	1	2	17.60	0	0
RENSSELAER POLYTECHNIC INSTITUTE	1	0	0.00	0	0
RICE UNIVERSITY	1	4	6.01	0	0
SANDIA CORP-SANDIA NATIONAL LABORATORIES	1	0	0.00	0	0
SANFORD-BURNHAM MEDICAL RESEARCH INST	1	5	9.61	0	0
SANGER INSTITUTE	1	0	0.00	3	4
SILBIOTECH, INC.	1	0	0.00	1	0
SINO AMERICAN CANCER FOUNDATION	1	0	0.00	1	0
SOMALOGIC, INC.	1	0	0.00	0	0
SRA INTERNATIONAL, INC.	1	0	0.00	0	0
STEMGENICS, INC.	1	0	0.00	0	0
SUPERIOR MICROPOWDERS, LLC	1	0	0.00	0	0
TARGET DISCOVERY	1	2	7.99	0	0
TEMPLE UNIV OF THE COMMONWEALTH	1	0	0.00	1	0
THERAJECT, INC.	1	0	0.00	2	0
THERMO FINNIGAN	1	0	0.00	0	0
THIRD WAVE TECHNOLOGIES	1	0	0.00	4	4
TVW TELETHON INSTITUTE-CHILD HEALTH RES	1	0	0.00	0	0

Institution Name	Number of Grants	Number of Publications	Average Impact Factor	Number of Patent Applications	Number of Patent Awards
TWIN LIGHTS BIOSCIENCE, INC.	1	4	11.97	0	0
TWISTNOSTICS, LLC	1	0	0.00	0	0
UNIVERSITY OF MEDICINE/DENTISTRY NJ-R W JOHNSON MEDICAL SCHOOL	1	4	4.07	1	0
UNIVERSITY OF AKRON	1	3	4.74	0	0
UNIVERSITY OF CALIFORNIA-LAWRENCE BERKELEY LAB	1	20	2.94	0	0
UNIVERSITY OF CALIFORNIA, SAN FRANCISCO	1	6	6.11	0	0
UNIVERSITY OF CINCINNATI	1	0	0.00	0	0
UNIVERSITY OF CONNECTICUT STORRS	1	2	0.00	0	0
UNIVERSITY OF ILLINOIS AT CHICAGO	1	4	5.27	0	0
UNIVERSITY OF MASSACHUSETTS AMHERST	1	0	0.00	0	0
UNIVERSITY OF MINNESOTA	1	9	4.70	0	0
UNIVERSITY OF MISSISSIPPI MED CTR	1	0	0.00	0	0
UNIVERSITY OF MISSOURI-COLUMBIA	1	19	7.15	0	0
UNIVERSITY OF RHODE ISLAND	1	2	5.69	1	0
UNIVERSITY OF ROCHESTER	1	0	0.00	0	0
UNIVERSITY OF SOUTH ALABAMA	1	14	5.28	0	0
UNIVERSITY OF SOUTHERN MISSISSIPPI	1	2	4.91	0	0
UNIVERSITY OF TOLEDO HEALTH SCIENCES CAMPUS	1	3	3.67	0	0
UNIVERSITY OF UTAH	1	15	6.51	0	0
UNIVERSITY OF VIRGINIA	1	0	0.00	0	0
UPPSALA UNIVERSITY	1	1	3.73	0	0
VACCINE RESEARCH INSTITUTE OF SAN DIEGO	1	0	0.00	0	0
VIVONETICS, INC.	1	1	0.00	0	0

Institution Name	Number of Grants	Number of Publications	Average Impact Factor	Number of Patent Applications	Number of Patent Awards
VTT/MSI MOLECULAR SCIENCES INSTITUTE	1	2	8.81	0	0
ATTAGENE, INC.	0	2	8.90	0	0
BIOTROVE, INC.	0	4	5.01	0	0
BUCK INSTITUTE FOR RESEARCH ON AGING	0	3	6.79	0	0
CATHOLIC UNIVERSITY OF AMERICA	0	4	4.51	0	0
CHILDREN'S HOSPITAL OF PHILADELPHIA	0	14	5.12	0	0
CHILDREN'S RESEARCH INSTITUTE	0	1	3.53	0	0
EASTERN VIRGINIA MEDICAL SCHOOL	0	12	5.03	0	0
HOWARD UNIVERSITY	0	11	5.64	0	0
ILLUMINA, INC.	0	3	4.65	0	0
IMMUNOTOPE, INC.	0	2	5.68	0	0
INDIANA UNIV-PURDUE UNIV AT INDIANAPOLIS	0	5	7.99	0	0
INSTITUT PASTEUR	0	2	12.08	0	0
LA BIOMED RESEARCH INST/ HARBOR UCLA MED CTR	0	2	5.61	0	0
LOUISIANA STATE UNIV A&M COL BATON ROUGE	0	14	4.75	0	0
PROTECH LABORATORIES, INC.	0	1	4.43	0	0
SIDNEY KIMMEL CANCER CENTER	0	15	8.75	0	0
SOUTHERN ILLINOIS UNIVERSITY CARBONDALE	0	1	5.68	0	0
STATE UNIVERSITY NEW YORK STONY BROOK	0	12	5.68	0	0
UNIVERSITY OF ALBERTA	0	2	4.82	0	0
UNIVERSITY OF GLASGOW	0	1	6.37	0	0
UNIVERSITY OF HOUSTON	0	2	5.23	0	0
UNIVERSITY OF MARYLAND BALTIMORE	0	20	4.32	0	0
UNIVERSITY OF MIAMI CORAL GABLES	0	1	4.64	0	0

Institution Name	Number of Grants	Number of Publications	Average Impact Factor	Number of Patent Applications	Number of Patent Awards
UNIVERSITY OF MIAMI SCHOOL OF MEDICINE	0	2	6.08	0	0
UNIVERSITY OF TEXAS ARLINGTON	0	1	8.81	0	0
TOTAL	**705**	**2198**	**3.23**	**237**	**125**

*The total number of Publications and Patent Applications represented in this table include publications and patent applications associated with multiple awards from different institutions. Therefore, the totals represented here are greater than the total number of publications and patent applications.

Appendix J – Principal Investigators with IMAT Awards

The following list represents the PD/PIs who have been recipients of IMAT awards since 1998, sorted in descending order by number of grant awards.

Table 35. PD/PIs with IMAT Awards

Principal Investigator (PD/PI)	Number of Grants	Number of Publications	Average Impact Factor	Number of Patent Applications	Number of Patent Awards
Makrigiorgos, G.	7	20	6.27	1	0
Vidal, Marc	6	42	12.41	0	0
Lam, Kit	5	58	4.70	7	4
Liotta, Lance	5	48	10.84	1	0
Chee, Mark	5	3	4.65	7	5
Moen, Phillip	5	0	0.00	0	0
Wang, Binghe	4	39	3.97	4	2
Tung, Ching-hsuan	4	30	4.69	0	0
Weier, Heinz-ulrich	4	19	2.92	1	0
Soper, Steven	4	16	4.77	1	0
Kron, Stephen	4	15	4.38	3	1
Wang, Yue	4	7	5.08	0	0
Larson, Dale	4	3	1.69	3	1
Jay, Daniel	4	1	0.00	5	1
Meyer, Tobias	4	0	0.00	2	3
Smith, Richard	4	0	0.00	0	0
Beebe, David	3	47	5.60	8	0
Woods, Virgil	3	46	6.55	1	1
Balgley, Brian	3	26	4.80	3	0
Kopelman, Raoul	3	24	5.50	0	0
Garraway, Levi	3	23	20.06	0	0
Haab, Brian	3	20	5.24	1	0
Tseng, Hsian-rong	3	20	10.92	1	0
Huang, Tim	3	14	7.58	0	1
Dovichi, Norman	3	13	4.39	0	0
Engelward, Bevin	3	13	3.85	5	3
Lizardi, Paul	3	12	5.07	1	0
Chen, Wen-tien	3	8	3.90	1	0
Fu, Xiang-dong	3	6	17.51	2	1
Sommer, Steve	3	6	4.34	0	0

Principal Investigator (PD/PI)	Number of Grants	Number of Publications	Average Impact Factor	Number of Patent Applications	Number of Patent Awards
Speicher, David	3	5	4.79	0	0
Mayer, Bruce	3	4	5.44	0	0
Rush, John	3	4	14.49	0	0
Majumdar, Arunava	3	3	8.91	6	2
Welsh, John	3	3	7.23	0	0
Zebala, John	3	3	3.56	2	0
Lim, Mark	3	2	0.00	0	0
Sutherland, John	3	2	2.87	0	0
Frank-kamenetskii, Maxim	3	1	4.00	0	0
Ferrari, Mauro	3	0	0.00	2	0
Guo, Baochuan	3	0	0.00	4	0
Malkhosyan, Sergei	3	0	0.00	0	0
Meldrum, Deirdre	3	0	0.00	0	0
Muddiman, David	3	0	0.00	0	0
Swenberg, James	2	30	4.32	0	1
Poole, Leslie	2	27	4.92	0	0
Ju, Jingfang	2	24	5.48	0	0
Cooper, Laurence	2	23	6.35	0	0
Macbeath, Gavin	2	22	7.86	0	0
Wang, Tza-huei	2	22	6.77	6	0
Szmacinski, Henryk	2	20	4.32	1	0
Goodlett, David	2	16	6.01	0	0
Shi, Huidong	2	16	5.25	0	0
Bogdanov, Alexei	2	15	3.16	1	1
Fortina, Paolo	2	14	5.12	1	0
Angeletti, Ruth	2	13	2.87	0	0
Gascoyne, Peter	2	13	4.43	2	1
Schmittgen, Thomas	2	10	4.56	0	0
Wang, Zhenghe	2	10	8.85	0	0
Dynan, William	2	9	3.53	1	0
Garner, Harold	2	9	4.68	3	1
Grzybowski, Bartosz	2	9	7.47	0	0
Harismendy, Olivier	2	9	9.14	0	0
Kandel, Eugene	2	9	4.52	0	0
O'leary, Timothy	2	9	3.55	1	1

Principal Investigator (PD/PI)	Number of Grants	Number of Publications	Average Impact Factor	Number of Patent Applications	Number of Patent Awards
Cote, Richard	2	8	6.53	2	1
Ji, Hanlee	2	8	8.75	1	0
Garciablanco, Mariano	2	7	8.54	1	0
Levenson, Richard	2	7	3.58	1	0
Ren, Bing	2	7	20.51	0	0
Schnitzer, Jan	2	7	15.86	4	0
Singer, Robert	2	7	9.70	2	0
Thomas, Nancy	2	7	2.57	1	0
Wigler, Michael	2	7	10.34	2	0
Crews, Craig	2	6	5.18	1	0
Zhou, Pengbo	2	6	7.24	0	0
Labaer, Joshua	2	5	15.73	3	1
Levy, Matthew	2	5	4.29	0	0
Sims, Christopher	2	5	4.89	0	0
Zhao, Yingming	2	5	6.08	0	0
Chodosh, Lewis	2	4	7.75	0	0
Parker, Laurie	2	4	4.39	1	0
Sherry, Dean	2	4	2.39	0	0
Claffey, Kevin	2	3	0.00	0	0
Faris, Gregory	2	3	4.41	0	0
Futscher, Bernard	2	3	6.31	0	0
Heyduk, Tomasz	2	3	4.42	5	4
Kelley, Shana	2	3	17.10	0	0
Minderman, Hans	2	3	0.00	1	0
Pallavicini, Maria	2	3	6.20	0	0
Skipper, Paul	2	3	4.58	0	0
Allbritton, Nancy	2	2	3.34	2	0
Bitter, Grant	2	2	8.29	2	0
Cleveland, William	2	2	1.13	1	1
Fresco, Jacques	2	2	4.79	0	0
Golovlev, Val	2	2	2.84	1	0
Griffith, Jeffrey	2	2	2.88	1	0
Hyslop, Terry	2	2	0.00	1	0
Krizman, David	2	2	5.11	0	0
Lee, Philip	2	2	2.22	0	0

Principal Investigator (PD/PI)	Number of Grants	Number of Publications	Average Impact Factor	Number of Patent Applications	Number of Patent Awards
Santangelo, Philip	2	2	6.17	0	0
Tempst, Paul	2	2	7.58	0	1
Weissman, Sherman	2	2	10.70	0	0
Yeung, Edward	2	2	4.30	0	0
Brock, Graham	2	1	6.37	0	0
Camp, Robert	2	1	0.00	0	0
Chance, Mark	2	1	10.27	0	0
Condeelis, John	2	1	0.00	1	1
Farkas, Daniel	2	1	0.00	0	0
Gale, James	2	1	0.00	0	0
Hunter, Ian	2	1	3.15	0	0
Kenan, Daniel	2	1	4.50	0	0
Shih, Ie-ming	2	1	14.50	0	0
Wind, Robert	2	1	3.47	0	0
Yee, Cassian	2	1	5.74	0	0
Barron, Annelise	2	0	0.00	0	0
Basedow, Robert	2	0	0.00	0	0
Becker, Christopher	2	0	0.00	0	0
Bieberich, Charles	2	0	0.00	0	0
Bogen, Steven	2	0	0.00	3	3
Cao, Han	2	0	0.00	2	0
Churchill, Gary	2	0	0.00	0	0
Dabora, Sandra	2	0	0.00	0	1
Davis, Ronald	2	0	0.00	0	0
Ellington, Andrew	2	0	0.00	0	0
Giese, Roger	2	0	0.00	0	1
Gite, Sadanand	2	0	0.00	0	0
Gorbovitski, Boris	2	0	0.00	0	0
Hanna, Michelle	2	0	0.00	1	0
Herlyn, Dorothee	2	0	0.00	0	0
Johnson, Paul	2	0	0.00	0	0
Kerr, William	2	0	0.00	0	0
Knapp, Daniel	2	0	0.00	0	1
Kogon, Alex	2	0	0.00	0	0
Lieber, Charles	2	0	0.00	3	8

Principal Investigator (PD/PI)	Number of Grants	Number of Publications	Average Impact Factor	Number of Patent Applications	Number of Patent Awards
Lifshitz, Nadia	2	0	0.00	0	0
Mehta, Anand	2	0	0.00	4	2
Olivi, Alessandro	2	0	0.00	0	0
Parkos, Charles	2	0	0.00	0	0
Seshi, Beerelli	2	0	0.00	0	0
Shackney, Stanley	2	0	0.00	0	0
Stanton, Martin	2	0	0.00	0	0
Steinman, Richard	2	0	0.00	0	0
Swanson, Basil	2	0	0.00	0	0
Ts'o, Paul	2	0	0.00	1	0
Wiktor, Peter	2	0	0.00	0	0
Willett, Catherine	2	0	0.00	0	0
Shaughnessy, John	1	32	11.43	16	11
Moore, Patrick	1	26	8.71	2	0
Yates, John	1	26	9.20	0	0
Chait, Brian	1	24	8.71	3	3
Chalmers, Jeffrey	1	22	2.98	0	0
Hahn, William	1	22	18.11	0	0
Aebersold, Ruedi	1	20	8.51	10	8
Zhang, Hui	1	19	5.68	2	0
Contag, Christopher	1	18	5.76	0	0
Taylor, Clive	1	18	3.79	1	0
Xu, Xiaowei	1	18	4.95	0	0
Chiu, Daniel	1	17	9.13	3	0
Koide, Shohei	1	16	9.31	0	0
Zhang, Jin	1	14	6.17	2	0
Clawson, Gary	1	13	6.74	0	1
Guthold, Martin	1	13	3.73	0	0
Drake, Richard	1	12	5.03	0	0
Jarvik, Jonathan	1	12	4.09	0	0
Kamm, Roger	1	12	5.31	0	0
Popescu, Gabriel	1	12	3.90	4	0
Baker, James	1	11	3.12	0	0
Charest, Joseph	1	11	5.19	0	0
Poola, Indira	1	11	5.64	1	0

Principal Investigator (PD/PI)	Number of Grants	Number of Publications	Average Impact Factor	Number of Patent Applications	Number of Patent Awards
Tang, Keqi	1	11	5.65	0	0
Tsourkas, Andrew	1	11	7.38	1	0
Wang, Shan	1	11	6.34	0	0
Issa, Jean-pierre	1	10	9.48	1	0
Nedelkov, Dobrin	1	10	5.86	3	2
Wong, David	1	10	6.74	0	0
Zu, Youli	1	10	6.28	0	0
Chaurand, Pierre	1	9	5.08	0	0
Gaasterland, Theresa	1	9	11.38	0	0
Lazar, Maria	1	8	4.05	0	0
Morris, David	1	8	9.21	0	0
Ramsey, John	1	8	5.07	0	0
Roninson, Igor	1	8	5.90	0	0
Kenis, Paul	1	7	6.12	0	0
Lee, Cheng	1	7	5.57	0	0
Liu, Guodong	1	7	4.84	0	0
Rao, Jianghong	1	7	16.92	1	0
Shendure, Jay	1	7	20.17	1	0
Waggoner, Alan	1	7	5.98	0	0
Wu, Mingming	1	7	3.78	0	0
Arap, Wadih	1	6	8.34	4	1
Barbas, Carlos	1	6	8.26	0	0
Boss, Gerry	1	6	5.27	0	0
Cravatt, Benjamin	1	6	16.83	0	0
Fowler, Carol	1	6	4.06	0	0
Hagedorn, Curt	1	6	8.56	0	0
Largaespada, David	1	6	6.12	0	0
Liu, Yang	1	6	3.55	1	0
Rehemtulla, Alnawaz	1	6	4.66	0	0
Rothstein, Rodney	1	6	5.23	1	0
Shibata, Darryl	1	6	6.00	0	0
Simberg, Dimitri	1	6	5.92	1	0
Tycko, Benjamin	1	6	9.08	0	0
Yin, Hang	1	6	3.30	0	0
Zhong, John	1	6	5.23	0	0

Principal Investigator (PD/PI)	Number of Grants	Number of Publications	Average Impact Factor	Number of Patent Applications	Number of Patent Awards
Burke, Peter	1	5	7.45	2	0
Chaput, John	1	5	5.14	0	0
Furdui, Cristina	1	5	7.72	0	0
Ghosh, Indraneel	1	5	5.50	1	1
Hakansson, Kristina	1	5	22.80	0	0
Lessnick, Stephen	1	5	5.71	0	0
Mcclelland, Michael	1	5	2.56	0	0
Milosavljevic, Aleksandar	1	5	6.38	0	0
Shea, Lonnie	1	5	4.63	0	0
Strauss, William	1	5	4.01	0	0
Turchi, John	1	5	7.99	0	0
Blair, Sarah	1	4	11.58	0	0
Chiles, Thomas	1	4	13.03	1	0
Diehl, Michael	1	4	6.01	0	0
Duffy, David	1	4	11.97	0	0
Evans, Conor	1	4	4.38	0	0
Gao, Jun	1	4	4.57	0	0
Gulley, Margaret	1	4	3.39	0	0
Hansen, Kirk	1	4	5.38	0	0
Huang, Songping	1	4	4.25	0	0
Lavie, Arnon	1	4	5.27	0	0
Li, Honghua	1	4	4.07	1	0
Lindsay, Stuart	1	4	6.20	0	0
Mach, Robert	1	4	4.28	0	0
Mccawley, Lisa	1	4	6.81	0	0
Morrison, Tom	1	4	5.01	0	0
Munn, Lance	1	4	3.78	0	0
Ong, Shao-en	1	4	11.52	0	0
Pun, Suzie	1	4	2.16	0	0
Rabinowitz, Joshua	1	4	20.91	1	0
Riehn, Robert	1	4	4.18	0	0
Schlegel, Richard	1	4	4.94	0	0
Soderling, Scott	1	4	6.11	0	0
Tackett, Alan	1	4	0.00	0	0
Waldman, Todd	1	4	18.31	3	0

Principal Investigator (PD/PI)	Number of Grants	Number of Publications	Average Impact Factor	Number of Patent Applications	Number of Patent Awards
Zeng, Gang	1	4	3.74	1	0
Bertics, Paul	1	3	6.53	0	0
Brown, David	1	3	4.10	2	0
Collins, Colin	1	3	6.02	0	0
Dunker, Alan	1	3	4.30	0	0
Fischbach, Claudia	1	3	7.00	0	0
Frankenburg, Shoshana	1	3	2.59	0	0
Held, Jason	1	3	6.79	0	0
Jin, Song	1	3	7.45	0	0
Kaufman, David	1	3	6.51	1	0
Knudsen, Beatrice	1	3	6.11	0	0
Krichevsky, Anna	1	3	4.83	1	0
Levchenko, Andre	1	3	0.00	0	0
Lu, Hang	1	3	6.53	0	0
Manalis, Scott	1	3	10.99	0	0
Mitra, Robi	1	3	4.43	0	0
Nettles, Kendall	1	3	11.94	0	0
Nolte, David	1	3	3.50	0	0
Porter, Marc	1	3	4.70	0	0
Revzin, Alexander	1	3	4.66	0	0
Saxena, Satya	1	3	2.72	0	0
Schroeder, Jane	1	3	1.69	0	0
Schwartz, David	1	3	3.08	0	0
Tavana, Hossein	1	3	4.74	0	0
Turk, Benjamin	1	3	4.37	0	0
Willey, James	1	3	3.67	0	0
Wirtz, Denis	1	3	5.51	0	0
Yamamoto, Fumiichiro	1	3	3.38	0	0
Aksan, Alptekin	1	2	2.51	0	0
Anderson, Karen	1	2	0.00	0	0
Andreev, Oleg	1	2	5.69	1	0
Bai, Mingfeng	1	2	8.31	0	0
Battrell, Charles	1	2	3.59	2	3
Bensimon, Aaron	1	2	12.08	0	0
Brent, Roger	1	2	8.81	0	0

Principal Investigator (PD/PI)	Number of Grants	Number of Publications	Average Impact Factor	Number of Patent Applications	Number of Patent Awards
Brown, Kathlynn	1	2	0.00	0	0
Cheng, Ji-xin	1	2	16.75	0	0
Ching, Jesus	1	2	5.57	0	0
Chuong, Cheng-ming	1	2	2.95	0	0
Davalos, Rafael	1	2	3.16	0	0
Diatchenko, Luda	1	2	8.90	1	1
Ding, Zhiyong	1	2	6.49	0	0
Gao, Xiaolian	1	2	5.23	0	0
Green, Roland	1	2	20.03	0	0
Hsi, Eric	1	2	3.43	0	0
Huang, Faqing	1	2	4.91	0	0
Keely, Patricia	1	2	12.11	0	0
Lai, Jonathan	1	2	3.52	1	0
Link, Darren	1	2	17.60	0	0
Lu, Chang	1	2	5.75	0	0
Maitra, Anirban	1	2	2.90	0	0
Nelson, Edward	1	2	3.66	0	0
Pannell, Lewis	1	2	5.36	0	0
Philip, Ramila	1	2	5.68	0	0
Resing, Katheryn	1	2	6.43	0	0
Richardson, Adam	1	2	18.94	0	0
Riethman, Harold	1	2	11.84	0	0
Robinson, Joseph	1	2	1.50	0	0
Schneider, Luke	1	2	7.99	0	0
Sikic, Branimir	1	2	8.84	0	0
Sun, Ye	1	2	2.93	0	0
Wang, Andrew	1	2	19.62	0	0
Waterman, Marian	1	2	19.68	0	0
Yao, Xudong	1	2	0.00	0	0
Agnew, Brian	1	1	5.48	0	0
Alexandrakis, Georgios	1	1	8.81	0	0
Anderson, N.	1	1	5.48	0	20
Bailey, Ryan	1	1	5.82	0	0
Baker, Laurence	1	1	4.63	0	0
Bao, Gang	1	1	0.00	0	0

Principal Investigator (PD/PI)	Number of Grants	Number of Publications	Average Impact Factor	Number of Patent Applications	Number of Patent Awards
Barrett, Michael	1	1	3.73	0	0
Beitz, Alvin	1	1	3.41	0	0
Brown, Brian	1	1	10.74	0	0
Butt, Tauseef	1	1	0.00	0	0
Chan, Doug	1	1	4.43	0	0
Chenchik, Alex	1	1	4.09	0	0
Chu, Wei-sing	1	1	1.10	0	0
Di Carlo, Dino	1	1	0.00	0	0
Edwards, Jeremy	1	1	2.55	0	0
Elenitoba-johnson, Kojo	1	1	4.12	0	0
Elledge, Stephen	1	1	31.15	0	0
Feng, Li	1	1	2.31	0	0
Gaston, Sandra	1	1	1.84	0	0
Gudkov, Andrei	1	1	0.00	0	0
Hulkower, Keren	1	1	3.53	0	0
Knowles, David	1	1	3.09	0	0
Kuhn, Peter	1	1	5.80	0	0
Landegren, Ulf	1	1	3.73	0	0
Li, Deyu	1	1	2.77	0	0
Liu, Yu-tsueng	1	1	3.22	0	0
Loge, Gary	1	1	3.08	0	0
Lu, Peter	1	1	4.22	0	0
Mostert, Michael	1	1	2.53	0	0
Murphy, John	1	1	0.00	0	0
Nolling, Jork	1	1	0.00	0	0
Oh, Seajin	1	1	5.09	2	0
Pan, Tingrui	1	1	5.75	0	0
Pasqualini, Renata	1	1	0.00	0	0
Porteus, Matthew	1	1	0.00	0	0
Reich, Daniel	1	1	5.70	0	0
Savran, Cagri	1	1	5.87	0	0
Segall, Jeffrey	1	1	3.02	0	0
Serbedzija, George	1	1	1.01	0	0
Shapiro, Benjamin	1	1	6.34	0	0
Shefer, Ruth	1	1	5.45	0	0

Principal Investigator (PD/PI)	Number of Grants	Number of Publications	Average Impact Factor	Number of Patent Applications	Number of Patent Awards
Shen, Lanlan	1	1	6.68	0	0
Sousa, Rui	1	1	15.28	0	0
Strauss, Steven	1	1	0.81	0	0
Superfine, Richard	1	1	13.77	0	0
Tainsky, Michael	1	1	2.42	0	0
Tao, Nongjian	1	1	8.60	0	0
Tolley, Luke	1	1	5.68	2	2
Van Dam, Robert	1	1	5.75	0	0
Wilson, James	1	1	4.64	0	0
Wyman, Robert	1	1	3.39	0	0
Zangar, Richard	1	1	5.15	0	0
Zeichner, Steven	1	1	3.53	0	0
Albertson, Donna	1	0	0.00	1	0
Bamdad, Cynthia	1	0	0.00	0	0
Bazar, Leonard	1	0	0.00	0	0
Beach, David	1	0	0.00	0	0
Beachy, Philip	1	0	0.00	0	2
Beaudenon, Sylvie	1	0	0.00	0	0
Bennett, Scott	1	0	0.00	0	0
Bestor, Timothy	1	0	0.00	0	0
Bradley, Allan	1	0	0.00	3	4
Brady, Erik	1	0	0.00	0	0
Burbulis, Ian	1	0	0.00	0	0
Caprioli, Richard	1	0	0.00	2	1
Caron, Marc	1	0	0.00	0	0
Cartegni, Luca	1	0	0.00	0	0
Castro, Carlos	1	0	0.00	0	0
Celedon, Alfredo	1	0	0.00	0	0
Chang, Hwai	1	0	0.00	0	0
Chiocca, E.	1	0	0.00	0	0
Cho, Raymond	1	0	0.00	0	0
Clary, Bryan	1	0	0.00	0	0
Cronin, Maureen	1	0	0.00	0	0
Cunningham, Brian	1	0	0.00	0	0
Decaprio, Anthony	1	0	0.00	0	0

Principal Investigator (PD/PI)	Number of Grants	Number of Publications	Average Impact Factor	Number of Patent Applications	Number of Patent Awards
D'errico, Francesco	1	0	0.00	0	0
Devere White, Ralph	1	0	0.00	0	0
Dolinger, David	1	0	0.00	0	0
Drees, Beth	1	0	0.00	0	0
Fan, Rong	1	0	0.00	0	0
Federspiel, Mark	1	0	0.00	0	0
Ferre, Francois	1	0	0.00	0	0
Furge, Kyle	1	0	0.00	0	0
Gau, Vincent	1	0	0.00	0	0
Gellibolian, Robert	1	0	0.00	0	0
Gerdes, John	1	0	0.00	0	0
Godley, Lucy	1	0	0.00	0	0
Goldrick, Marianna	1	0	0.00	0	0
Gordon, Neal	1	0	0.00	0	0
Greis, Kenneth	1	0	0.00	0	0
Haddad, Bassem	1	0	0.00	0	0
Hagen, Frederick	1	0	0.00	0	0
Hahn, Kristine	1	0	0.00	0	0
Hampden-smith, Mark	1	0	0.00	0	0
Hancock, Lawrence	1	0	0.00	0	0
Heilig, Joseph	1	0	0.00	0	0
Henkens, Robert	1	0	0.00	0	0
Hirschowitz, Edward	1	0	0.00	0	0
Hrudka, Brian	1	0	0.00	0	0
Hsiao, Shih-chia	1	0	0.00	0	0
Israel, Barbara	1	0	0.00	0	0
Janzen, William	1	0	0.00	0	0
Jeffrey, Stefanie	1	0	0.00	0	0
Kassis, Amin	1	0	0.00	0	0
Kim, Raymond	1	0	0.00	0	0
Kravitz, Rachel	1	0	0.00	0	0
Lai, James	1	0	0.00	0	0
Landers, James	1	0	0.00	0	0
Latham, Gary	1	0	0.00	1	1
Lawrence, David	1	0	0.00	0	0

Principal Investigator (PD/PI)	Number of Grants	Number of Publications	Average Impact Factor	Number of Patent Applications	Number of Patent Awards
Lee, Brian	1	0	0.00	0	0
Levenson, Victor	1	0	0.00	1	1
Lin, Emme	1	0	0.00	0	0
Liu, Edison	1	0	0.00	0	0
Loken, Michael	1	0	0.00	0	0
Lu, Chiung-mei	1	0	0.00	0	0
Martin, Mark	1	0	0.00	0	0
Mathew, Anu	1	0	0.00	0	0
Mc Garrity, Gerard	1	0	0.00	0	0
Mc Gown, Linda	1	0	0.00	0	0
Mcdonald, John	1	0	0.00	0	0
Medghalchi, Susan	1	0	0.00	0	0
Messmer, Bradley	1	0	0.00	0	0
Messmer, Davorka	1	0	0.00	0	0
Miller, Jeffrey	1	0	0.00	0	0
Mo, Yin-yuan	1	0	0.00	0	0
Monforte, Joseph	1	0	0.00	3	1
Moon, John	1	0	0.00	0	0
Morachis, Jose	1	0	0.00	0	0
Neri, Bruce	1	0	0.00	4	4
Nielsen, Ulrik	1	0	0.00	0	0
Nilsen-hamilton, Marit	1	0	0.00	0	0
Oliner, Jonathan	1	0	0.00	0	0
Ozers, Mary	1	0	0.00	0	0
Pamula, Vamsee	1	0	0.00	0	0
Paris, Mark	1	0	0.00	0	0
Patricelli, Matthew	1	0	0.00	0	0
Paulovich, Amanda	1	0	0.00	0	0
Perlin, Mark	1	0	0.00	0	0
Piccoli, Steven	1	0	0.00	0	0
Quinn, Thomas	1	0	0.00	0	0
Rampersaud, Arfaan	1	0	0.00	0	0
Rao, Chandra	1	0	0.00	0	0
Renard, Andre	1	0	0.00	0	0
Richterich, Peter	1	0	0.00	0	0

Principal Investigator (PD/PI)	Number of Grants	Number of Publications	Average Impact Factor	Number of Patent Applications	Number of Patent Awards
Rogers, Rick	1	0	0.00	0	0
Ruan, Biao	1	0	0.00	0	0
Ruiz, Joseph	1	0	0.00	0	0
Sheldon, Edward	1	0	0.00	0	0
Shen, Li	1	0	0.00	0	0
Shen, Shanxiang	1	0	0.00	0	0
Siegmund, Kimberly	1	0	0.00	0	0
Smith, Lloyd	1	0	0.00	3	0
Sood, Anup	1	0	0.00	0	0
Spencer, Forrest	1	0	0.00	0	0
Squillante, Michael	1	0	0.00	0	0
Straume, Tore	1	0	0.00	0	0
Sulk, Roberta	1	0	0.00	0	0
Tang, Cha-mei	1	0	0.00	0	0
Tanner, Scott	1	0	0.00	0	0
Tolias, P.	1	0	0.00	0	0
Tolias, Peter	1	0	0.00	0	0
Trnovsky, Jan	1	0	0.00	0	0
Tyrrell, Steven	1	0	0.00	0	0
Vykoukal, Jody	1	0	0.00	0	0
Wang, Jiwu	1	0	0.00	0	0
Wang, Nicholas	1	0	0.00	0	0
Wang, Pencheng	1	0	0.00	1	3
Warren, Christopher	1	0	0.00	0	0
Watt, Paul	1	0	0.00	0	0
Weaver, Daniel	1	0	0.00	0	0
Williams, John	1	0	0.00	0	0
Winzer-serhan, Ursula	1	0	0.00	0	0
Wood, Katherine	1	0	0.00	0	0
Xanthopoulos, Kleanthis	1	0	0.00	0	0
Xie, Xiaoliang Sunney	1	0	0.00	0	0
Xu, Baogang	1	0	0.00	0	0
Yang, Chihae	1	0	0.00	0	0
Yang, Xing	1	0	0.00	0	0
Yannelli, John	1	0	0.00	0	0

Principal Investigator (PD/PI)	Number of Grants	Number of Publications	Average Impact Factor	Number of Patent Applications	Number of Patent Awards
Yen, Yun	1	0	0.00	1	0
Zauderer, Maurice	1	0	0.00	0	0
Zou, Nianxiang	1	0	0.00	0	0
Zwick, Michael	1	0	0.00	0	0
TOTAL	**705**	**2127**	**3.98**	**237**	**125**

*The total number of Publications and Patent Applications represented in this table include publications and patent applications associated with multiple awards with different principal investigators. Because of this the totals represented here are greater than the total number of publications and patent applications.

Appendix K – Preceding Technologies

This appendix presents data provided in an open text field in response to the survey question "*Please list any preceding technology(s) or methodology(s) for which your own technology or methodology offered superior performance capabilities. Please list no more than five, separated by a semi-colon*."

- [99mTc]sestimibi
- Aliquotting before freezing the biospecimen: this technology is faster and less expensive / 2. freeze/thaw cycling: this technology is faster and less expensive and produces samples of higher quality
- 1D-electrophoresis; MS/MS
- 2-D gel electrophoresis / Tissue proteomics
- 2-dimensional gel electrophoresis; Edman protein sequencing; SDS-PAGE
- 96-well stopper based Oris Cell Migration Assay; Boyden chamber; scratch assay, microfluidic assays
- Affinity chromatography; immunoprecipitation; dialysis; mass spectrometry
- Affinity purification
- Affinity purification of targets with chemical cleavage for elution or elution by denaturation
- Affymax peptide microarray technology
- Allele-specific PCR; ChIP-seq; Luciferase assay; GWAS (genome-wide association studies); fluorescence polarization
- Ammonium salt of iron citrate; manganese chloride and gadolinium-incorporated zeolites
- Analysis of platelet aggregation
- Antibody development
- Antigen retrieval; heat-induced antigen retrieval
- Anti-phospho antibodies for quantifying phosphorylated kinase substrates
- Any enzyme coupled screening readout (i.e. ADP-Hunter); Fluorescent or Chemi-luminescent readout assays
- Any form of assay/test incubation
- Any mutation detection technology utilizing PCR; Sanger sequencing; Massively parallel sequencing; High Resolution Melting for mutation detection; methylation detection
- AOTF-based multispectral imaging; Sagnac interferometer-based multispectral imaging; conventional brightfield microscopy; conventional fluorescence microscopy
- ApoCell
- Apoptosis assay; metabolism assay
- Arbitrary antigen selection. Selection of just whole proteins for vaccine development
- BAC microarrays
- Bait hybridization, PCR amplicon sequencing, molecular inversion probe targeting, Haloplex targeted sequencing, sanger PCR sequencing
- Bait-hybridization technology for targeted sequencing offered by Illumina, Agilent and Nimblegen. It provides rapid analysis and capture with less work
- BEAMING; Cold-PCR; Sanger Sequencing; Exome Sequencing
- Biobanking; macrodissection; extraction of nucleic acid; amplification; sequencing
- Biomarker; sequencing

- Blackman, M. L.; Royzen, M.; Fox, J. M. "The Tetrazine Ligation: Fast Bioconjugation Based on Inverse-electron-demand Diels-Alder Reactivity," J. Am. Chem. Soc. 2008, 130, 13518–13519
- Boyden Chamber assay, H&E staining
- Cancer detection methods
- Cantilever-based detection, Quartz Crystal Microscopy, Fluorescence
- Capillary gel electrophoresis; microarrays
- Capture of circulating cancer cells using specific antibodies
- CEA serology by ELISA
- Cell Magneto-rotation was preceded by another technology applied to bacteria, called AMBR (Asynchronous Magnetic Bead Rotation)
- Cell penetrating peptides (CPP) are not specific and toxic, no successful applications were reported in animals or humans. In contrast to CPP, pHLIPs are membrane peptides, nontoxic, pH specific and provide highly specific delivery of various cargo molecules and nanoparticles to diseased tissue
- Cell search; Micro Hall; PCR (Polymerase Chain Reaction); MDA (Multiple displacement Amplification)
- CellSearch
- CellSearch Assay
- CellSearch cancer cell detection platform; EPCAM epithelial tumor cell marker
- CellSearch EPCAM cell enrichment method for gene expression profiling
- CellSearch platform
- CellSearch technology; microfluidic system; filtration based cell separation system
- CellSearch tumor cell enrichment platform; EPCAM epithelial marker for capturing tumor cells
- Cellsearch, magnetic activated cell sorting, fluorescence activated cell sorting
- Chimeric mouse models; single transgenic mouse lines
- ChIP-on-Chip; Differential Methylation Hybridization (DMH); MeDIP-Chip;
- Chromium cytotoxicity assay, LDH cytotoxicity assay
- Chromosome-based comparative genomic hybridization
- Circulating tumor DNA
- Cloning of mutant alleles following site-directed mutagenesis; screening mutant proteins for altered function by enzyme assays
- Commercially available mineralized culture plates
- Comparative analysis followed by functional confirmation of candidates/conventional insertional mutagenesis followed by functional confirmation of candidates
- Conventional histology (gold standard), phase-contrast microscopy, electron microscopy
- Conventional pathology
- Conventional sampling of tissue specimens by shave or "divot" collection methods (limited to relatively large tumors that are visible in the gross specimen); inappropriate utilization of FFPE specimens for molecular analyses because snap frozen specimens were not available
- Conventional scale HPLC
- Conventional insertional mutagenesis. Forward genetics by screening effector libraries
- CT scan; MRI
- Current generation of calorimeters sold by GE-Microcal and TA
- Decellularized tissue; collagen; matrigel
- Digene Hybrid Capture; FISH; reverse hybridization HPV line probe assay

- Direct detection of DNA adducts by mass spectrometry; detection of DNA adducts by 32P-postlabeling
- DNA methylation microarray; Bisulfite genomic sequencing; Bisulfite pyrosequencing
- Dynalbeads (Life Technologies); MACS (Miltenyi Biotec)
- Ectopic expression of epitope-tagged cDNA transgenes
- ELISA (enzyme-linked Immunosorbent Assays)
- ELISA, high sensitive ELISA, Immuno-PCR
- ELISA; electrochemiluminescence; xMAP; Erenna; chemiluminescence
- ELISA; ELISPOT; FLUOROSPOT; Flow cytometry
- ELISA; fluoroimmunoassays; fluorescence polarization assays
- ELISA; Western blot; microarrays for miRNA analysis; qRT-PCR for miRNA analysis (in terms of multiplexing capacity)
- Empiric selection of drugs for patients with metastatic cancer
- Energy transfer indicators; mass spectrometry; gene sequencing
- Enzyme-linked immunosorbant assay; Lectin assay
- Existing Tissue proteomics protocols including all tested commercial and academic protocols tested. / One of the methodologies used in our technology was commonly used in the 70's and 80's by biochemists but without an accurate and sensitive method for characterizing protein products
- Expression-based proteomics and genomics, which may not accurately measure changes in protein function
- FACS / Cell Search
- FISH (fluorescence in situ hybridization)
- FISH; DNA Probes
- FISH; RT-PCR
- Flow cytometry. As there were very few methods for detecting CTCs in blood, and the CellSearch procedure was just entering clinical use. Now there are many CTC techniques
- Flow cytometry; ELISA
- Flow sorting; PCR; histopathology
- Fluorescence Correlation Spectroscopy (FCS), Raster Image Correlation Spectroscopy (RICS)
- Fluorescent tagging
- Formalin, Bouins fixative, RNA later, Paxgene
- Formalin, RNA later; UMFIX; Zenkers; Acid decalcification
- Förster resonance energy transfer (FRET)
- FR-based drug delivery system in general
- Gamma-H2AX immunostaining
- Gel isoelectric focusing; capillary isoelectric focusing; multi compartment electrolyzer
- Gel shift assays, ELISA
- Gene expression microarrays from various vendors as well as made in-house (e.g., using pin-spotting)
- Gene-trapping
- Genotyping with very few genetic markers; genotyping with a large amount of material; genotyping with materials with heterogeneity; genotyping with low sensitivity
- Global cloning without selection

- Hanging drop spheroid technique; microfluidics spheroid technique; rotary flask spheroid technique; micro wells spheroid technique
- Heat-induced antigen retrieval; antigen retrieval
- High throughput protein trafficking assays for drug discovery, targeting physiological biosensors for pathway measurements in live cell function
- Hisotpathology of five micron tissue sections; selective analysis of microvessel; microvessel tortuosity
- HITS-CLIP
- Hybdrization arrays, cytogenetics, DNA sequencing
- Hybrid capture
- Hydrogen-deuterium exchange mass spectrometry
- Illumina 450K array methodology
- Illumina Goldengate DNA methylation arrays
- Imaging; drug delivery
- Immunoassays / Mass spectrometric assays lacking specific affinity enrichment
- Immunohisochemical imaging / Conventional IHC-based fluorescence imaging / Hyperspectral Imaging / Chemical and electrical elution of antibodies
- Immunohistochemistry
- Immunohistochemistry with phosphospecific antibodies
- Immunohistochemistry; gene expression profiling
- Immunohistochemistry; Immunofluorescence
- Immunohistochemistry; in situ hybridizaztion; Pap smear
- Immunohistochemistry; western blotting; ELISA
- Immunomagnetic isolation, flow cytometry, fluorescent probes
- Immunoprecipitation; affinity chromatography; mass spectrometry MRM; dialysis
- Immunoslotblot methods for abasic sites in DNA
- Immuno-staining in electron microscopy
- In principle, could have been superior to: genetically engineered FRET biosensors; in vitro kinase assays
- In vitro kinase assays using purified proteins
- In vitro kinase assays; genetically-engineered cell based kinase assays; MRM/targeted MS for endogenous proteins
- Individual target screening
- Inductively Coupled Plasma Mass Spectrometer; Dynamic Reaction Cell for ICP-MS; Mass Cytometry; metal-chelated polymers
- Intensity based mass spectrometry
- Isothermal whole genome amplification; PCR-based whole genome amplification
- Kinase substrate tracking and elucidation (KESTREL)
- LC-MS; SRM MS
- Lectins
- Lectins, antibodies
- Liposome mediated drug delivery
- Liquid chromatography tandem mass spectrometry
- Long-range paired-end sequencing using Sanger method

- Low-density microarray platforms; high-density but low sample throughput microarray platforms
- MACS, magnetic cell separation
- Magnetic beads
- Manual data analysis
- Manual sample preparation of cells
- Many methods of analyzing excised tissues for biological events
- Mass spectrometry
- Mass Spectrometry of DNA adducts; ChIP-Seq of DNA repair proteins; TUNEL assays
- May be able to detect biomolecules, including protein without any modification
- MeDIP-based on methyl-cytosine binding proteins; HELP-based on HpaII digestion
- Metal enhanced fluorescence, protein microarrays, ELISA assays, Luminex technology
- Methylation Specific PCR; Bisulfite Sequencing; Methylation Analysis Arrays
- Methylation specific sequencing; FISH assays
- Methylation-specific PCR; MethylLight; Methylation Sensitive Restriction Enzyme - PCR, MethylScreen
- MHC class II restricted peptides as cancer vaccines
- Microarray / PCR
- Microarrays, Systematic Evolution of Ligands by Exponential Enrichment (SELEX)
- Microfluidic imaging devices with non-MS detection (developed by others)
- Microscopy with a human observer/operator; flow cytometry
- Molecular beacons
- Molecular clock
- Monoclonal antibodies; aptamers; peptides
- Monoclonal library screening, chemical library screening
- Monolayer drug screening technologies
- Most systems use optical detection of fluorescent labels. The use of radiolabels permits greater flexibility and can be used in place of, or in conjunction with optical techniques
- MRI contrast agents, DTPA
- MRM MS; SRM MS; TMT; iTRAQ; Immunoassays
- MSE, SWATH
- Multi cell counting; rare cell capture from whole blood
- Multiparameter Flow cytometry; bone marrow biopsies
- Multiplexed protein measurement; protein quantitation, protein identification
- Naked affibody / naked antibody / naked DARPin / nucleoside analogs by themselves
- Nano-ChIP-seq, LinDA, iChIP
- Near infrared fluorescence imaging, photoacoustic imaging
- Needle localization, radioactive seed localization
- Next generation sequencing, quantitative PCR, quantitative RT-PCR
- None/NA (n=21)
- Northern blots; Sanger sequencing of RNA libraries
- NSOM: same basic resolution but much higher throughput / HELM/STED: same basic resolution but no bleaching of hte sample
- OBOC; microarray; microplate
- Oligo ligation assay (OLA)

- Oligonucleotide; aptamer; circulating tumor cells; one-step; detection
- OroSure, Salivmetrics, Salivette
- Other fluid pumping methods
- OxICAT; biotin-switch; redox-DIGE
- PCR screening; hybridization assays; immunoassays
- PCR; LAMP; TMA; B-DNA, bisulfite-based DNA methylation detection
- PCR-based detection, immunoassay, microarray, robotic lab automation
- PCR-based mutation detection technologies
- Permethylation (QUIBL)
- Petri dish culture methods
- Plasmoduction using a karyogamy deficient mutation
- Polyclonal antibody; monoclonal antibody
- Positional scanning peptide libraries; oriented peptide libraries; other peptide microarray methods
- Presence or absence of genetic, epigenetic or other biomarkers within an individual tumor
- Previous technology centered on exogenous probes; we were developing ways to understand endogenous signals and metabolic changes in situ
- Previous telomere length and telomere dysfunction assays
- PROTACs
- Protein cross linking; deuterium exchange; crystallography of multi protein complexes
- Protein spotted arrays, immunprecipitation, biochemistry
- Quantitative real-time PCR, Northern blots, Immunocytochemistry
- Random array of passively-cooled biospecimen cryopreservation and transport modalities which offer unreliable and inconsistent results.
- Real time PCR; capillary electrophoresis; multicolor fluorescence detection; single photon detection
- Real-time PCR
- Representational difference analysis / Semi-conserved PCR /
- RNA aptamer-tagging; Classic biochemical purification; in vitro approaches with extracts
- RNAi genetic screen, transposon-mediated mutagenesis, gene trap technology
- Rotary evaporation; micro-rotary evaporation
- RT PCR
- RT PCR for transcription factors, western blotting
- RT-PCR / Microarray
- Sandwich ELISA; Immunohistochemistry
- Screening of protein adducts by MS-based approaches
- Screens for orphan receptors that focused strictly on ligand =-receptor binding (e.g., Invitrogen polar screen bindings). Screens for nuclear hormone receptor functionality that used cell-based assays (e.g. transfected reporter constructs)
- Selection of genetic suppressor elements or shRNAs from libraries generated in retroviral vectors
- SELEX; SERPA; Hybridoma
- Self-luminating Quantum dots
- Sensor-seq has superior performance capabilities to molecular profiling of microRNAs as it enables microRNA activity to be measured - this is a biological readout

- Sequencing methods. Digital PCR platforms
- Sequencing; microarrays; PCR
- Serum PSA; PCA3
- Si microfabricated AFM tips, and variations of this commercial technology
- Single Cell Multiplex Protein Secretion Profiling Technology (single cell proteomic barcode chip); DNA-encoded antibody library technology
- SISCAPA; magnetic beads; LC-MS; ziptips
- Slot blot analysis of apurinic sites in DNA; many DNA damage assays that require millions of genome equivalents of DNA to make various DNA damage measurements because this assay can be done with as few as five cells and yields low variance measurements
- Small molecule fluorescence assays
- Southern blot hybridization assay
- Southern blots
- Split-protein, PCA
- Spotted peptide arrays; Lithographic peptide arrays; ELISA assays
- Standard cell culture methods, transwell culture methods, monoculture methods, in vivo experiments
- Standard DNA methylation micrroarray analysis
- standard metastasis assay
- Standard microarrays
- Standard morpholino gene knock-down
- Standard RNA extraction methods
- Standard sample preparation methods
- Standard small molecule chemical library methods
- Standard, low-throughput restriction digestion-based cloning; use of non-normalized cDNA libraries for cloning and for screening; low-sensitivity and low-specificity interaction mapping technologies
- Strong cation exchange chromatography; multidimensional protein identification technology; gel electrophoresis; zoom IEF
- surface plasmon resonance, quartz microbalance, optical interference, fluorescence detection
- surface-pattern based cell co-culture; reversible-bonding based cell co-culture
- Targeted mass spectrometry
- Test-tube PCR.
- The preceding technology was performance of the process by hand (manual method).
- The technology was very new at the time; 454 sequencing; Sanger sequencing
- tissue stain followed by microscopy / tissue punches followed by normal proteomics
- Tissue-specific cre-recombinase / Exosome-based therapeutics
- Traditional restriction digestion/ligation-based cloning; traditional cDNA libraries for screening; manual, low-throughput cloning and screening; low-sensitivity and low-specificity interaction screening
- Transwell or standard cell migration assays; animal models of metastasis
- Unmed need, Require small number of cells, Robust
- Used standard technology but in a new way
- Veridex

- We have a water quality analyzer that is now used as permanent hardware on the International Space Station, but does not have the capabilities to meet the needs of this current project
- We vastly improved upon gross microdissection of tumors by building a machine to do the same. / Coupled with vertical arrays, this was capable of yielding a very detailed gene expression picture of single tumors, albeit at significant cost
- Western Blots; Q-PCR;Dot Blots;Spotted DNA Microarrays
- Yeast two hybrid

Appendix L – Funded Technologies and Methodologies

This appendix presents the trademarked or formally designated names of the technologies or methodologies funded under the IMAT grant[37] (n=267) by reported stage of development (reported between June and September 2015) in alphabetical order.

Concept Only (n=3)

- AQUA
- Multiplexed assays
- None

Prototype Development/Testing Stage (n=61)

- Affibody; Herceptin; DARPin
- ALBUMS
- Aptamer-based biosensing
- Automated minimal residual disease quantification
- Autonomous microscopy and manipulation of cells
- Biomatrix scaffolds
- Bivalent Affinity Reagent (BAR)
- Cancer diagnostics
- Capillary electrophoresis
- cDEP
- CHAMP
- Chemosensor (n=2)
- Chemosensors
- CSOD
- CTCellect
- Digital Protein Analysis
- DNA origami
- Epitope Cloning
- eSystem
- FLIVO
- Folate receptor based delivery
- Footprinting
- Grating coupled surface plasmon resonance/coupled emission
- Hairpin-PCR
- Highly modified nucleic acids
- Intestinal Selection of Immunogenic Antigens (ISIA)
- MALDI imaging
- MEFspot
- Microfluidic Oscillatory Washing based ChIP-Seq
- Microfluidics
- MIP CHIP
- None / No / N/A / No Trademark (n=15)
- OBOC
- OxMRM
- ParaCEST, T1 based gadolinium agents
- PD-loop technology
- Peptide microarrays
- PROTAC
- Quantum dots-FRET
- Simulation model of tumor growth
- Single-molecule aptamer selection method
- SNAP-Tide
- Surface proteome signatures
- Surface-enhanced Raman spectroscopy (SERS) nanosensors
- Telomere DNA content
- Trip-chip

[37] Technology names are only provided for those grantees that responded to the Web-based survey

Full Development/Testing Stage (n=56)

- A+PSA
- Avian Leukosis Viruses and Polypeptide Display
- BUBLES (BUoyancy enaBLEd Separation)
- Cancer diagnostics
- Cell Magnto-rotation
- Cell-CT
- COLD-ddPCR
- CyTOF, MaxPar
- DeNAno
- Digital transcriptome subtraction
- Dynamic isoelectric focusing
- Edgotyping; edgetic profiling
- EET - Endogenous Epitope Tagging
- Exclusion-Based Sample Preparation
- FALI
- Fluorescence Correlatin Spectroscopy (FCS)
- Fluorescent Lifetime Imaging Microscopy
- Genetic suppressor elements
- High-throughput genotyping
- Interactome mapping
- IRIF analysis
- Large Area POsition Sensitive avalanche photodiodes: PS-APD
- LC-MS/MS
- Mass tags
- MCA
- Microfluidic cell separation
- Microfluidics for cancer chemotaxis
- Mineralized 3-D tumor models
- Modified MTRIPs and PLA
- No / None / N/A (n=8)
- Nanocoax
- OBOC encoded small molecule libraries
- PC-SNAG
- Photonic Crystal Enhanced Fluorescence
- Pressure-Assisted molecular recovery
- PRISM-SRM MS
- ProCure Device
- Ratiometric BiMolecular Beacon
- RCA-RCA genome amplification
- Reactivation
- Reverse in-gel kinase assay
- Self-assemblying magnetic nanoparticles
- Single Molecule Scanning
- SNP-SNAP microarray
- Stimuli-responsive reagents
- Synthetic dosage lethality
- Tadpoles
- TRACER

Pre-Clinical Development (n=56)

- Automated glycopeptide analysis
- BUBLES
- Chemical cytometry
- Circulating tumor cell detection
- CLCchip
- Crainbow
- CTC gene expression profiling
- Electrowetting on Dielectric (EWOD or EWD)
- Enhanced Formalin
- ErasableImagingProbes
- Fluorescence in situ hybridization (FISH)
- Fluorescent Amplification Catalyzed by T7 RNA polymerase Technology
- FSCE
- Functionalized nanohydrogels
- Glycomics
- High-throughput DNA methylation
- Illumina Goldengate
- Imaging splicing in vivo
- Immuno-MRM
- In vivo cycloadditon chemistry
- In vivo phage display
- Invasive circulating tumor cells (iCTCs)
- Inverted single strand capture
- Isothermal vitrification matix
- Microfilter Technology for CTC Capture
- MicroRNA targeting

- Microscopy
- Molecular Inversion Probes
- MRM assay for kinase biosensor
- No / None / N/A (n=7)
- Nanoparticles
- NanoVelcro CMC Assays
- NAPPA
- Patient-derived antibody isolation and selection
- Patient-derived anti-cancer antibodies
- PB Oraltrast
- pHLIP technology
- Population genetics
- Prostate cancer biomarkers
- Proteomics
- QD-BRET
- QMS
- RAP-PCR
- Reverse in-gel kinase assay
- Silicon photonic microring resonators
- Spatial-domain low-coherence quantitative phase microscopy (SL-QPM)
- STAndardized Rna SEQuencing (STARSEQ)
- Suspended microchannel resonator
- Tissue Print Technologies
- Vortex chip

Commercially Available (n=62)

- ABPP
- Abscription (Abortive Transcription)
- Array comparative genomic hybridization
- BeadArray(TM) Gene Expression Arrays
- Bridge-It
- CD-tagging
- CellASIC (R)
- COLD-PCR
- CryoXtract
- ECM proteomics
- FISH&CHIPS
- Fluorescent biosensors
- Haplo Insufficiency Profiling
- Hybridizer
- Imaging mass spectrometry
- In vivo bioluminescence imaging
- INLIGHT
- Interactome mapping
- Liquid Tissue
- MAS
- Mass spectrometry (n=2)
- Mass spectrometry analysis of protein mixtures
- Massquirm
- MethylMeter(r)
- Microfluidics
- MS2-BioTRAP
- MSIA and BRP
- No / None / N/A / Unknown (n=4)
- Nanotrap (n=2)
- NanoVelcro CTC Assay (n=2)
- Nuance and Vectra
- Optical Mapping
- Oris Pro
- OS-Seq (Oligonucleotide-Selective Sequencing)
- Passive pumping
- PCR
- Polony Sequencing
- Protein footprinting
- Protein painting
- Proximity ligation assays or PLA
- Quantifiable Internal Reference Standard
- RASL/DASL (n=2)
- Recognition Imaging
- RNA•PRO SAL
- SEER, split-protein
- Sensor-seq
- Sentrix(TM) Array Matrix
- Simoa
- SISCAPA
- SMARTChips
- SNLS 2200 Light Activation System™
- Targeted sequencing
- Theralin (n=2)

Discontinued (n=17)

- AIM
- Carbon nanotube AFM probes
- DNA methylation analysis
- Enzyme Inhibitor Screening by MS
- Kinase assay
- Meso Scale Diagnostics, LLC. (MSD) MULTI-ARRAY® technology
- Microcantiliver biodetector
- No trademark; antibody based microarray to detect DNA-RNA hybrids
- None (n=2)
- Peptide microarray
- Rolling Circle Amplification
- Sensor platform
- Sigma-1 Receptor Radiotracer
- SNE in Neuroblastoma
- SNIPase detection platform
- Vertical Arrays

Don't Know (n=4)

- Biosensors
- Nanoliter scale PCR, telomerase detection
- Parallel Peptide Tandem Mass
- Single-molecule imaging
    -

Missing (n=8)

- Flow cytometry PCR
- Fluorescent kinase probes (kProbes)
- IPAT
- No / None / N/A (n=5)

Appendix M – Abbreviations

Table 36. Abbreviations Used in this Report

Abbreviation	Definition
ACS	American Cancer Society
AIDS	acquired immunodeficiency syndrome
ATP	Advanced Technology Program
BIOSP	biospecimen
BISTI	Biomedical Information Science and Technology Initiative
CDC	Centers for Disease Control and Prevention
CEO	Chief Executive Officer
CIP	Cancer Imaging Program
COLD-PCR	co-amplification at lower denaturation temperature-polymerase chain reaction
CRO	contract research organization
CSSI	Center for Strategic Scientific Initiative
DARPA	Defense Advanced Research Projects Agency
DNA	deoxyribonucleic acid
DoD	U.S. Department of Defense
EAC	Evaluation Advisory Committee
EMAT	Emerging Molecular Analysis Technologies
FDA	U.S. Food and Drug Administration (FDA)
FOA	Funding Opportunity Announcement
FY	fiscal year
HHS	U.S. Department of Health and Human Services
IC	Institutes and Centers
IEEE	Institute of Electrical and Electronics Engineers
IMAT	Innovative Molecular Analysis Technologies
IRB	institutional review board
ITCR	Informatics Technology for Cancer Research

Abbreviation	Definition
MS Access	Microsoft Access
NCI	National Cancer Institute
NCRR	National Center for Research Resources
NIBIB	National Institute of Biomedical Imaging and Bioengineering
NIGMS	National Institute of General Medical Sciences
NIH	National Institute of Health
NIST	National Institute of Standards and Technology
NSF	National Science Foundation
OMB	Office of Management and Budget
PA	Program Announcements
PD/PI	Program Directors/Principal Investigators
PNAS	Proceedings of the National Academy of Sciences
QC	quality control
QVR	Query View Report
R&D	research and development
RFA	Request for Applications
RFP	Request for Proposals
Ripple Effect	Ripple Effect Communications, Inc.
RNA	ribonucleic acid
SBIR	Small Business Innovation Research
SME	subject matter expert
SOW	Scope of Work
SPIRES	Scientific Publication Information Retrieval and Evaluation System
STPI	Science & Technology Policy Institute
STTR	Small Business Technology Transfer
USPTO	United States Patent and Trademark Office