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Principal Investigator: Rogers, Juan D.
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Submitted By:
Rogers, Juan - Principal Investigator
Title:
Assessment of Fifteen Nanotechnology Science and Engineering Centers? (NSECs) Outcomes and Impacts: Their contribution to NNI Objectives and Goals

Project Participants

Senior Personnel

Name: Rogers, Juan
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Porter, Alan
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Shapira, Philip
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Youtie, Jan
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Rodriguez, Laura
Worked for more than 160 Hours: No
Contribution to Project:
Data entry and cleaning, spreadsheets and other data management functions.

Post-doc

Graduate Student

Name: Kay, Luciano
Worked for more than 160 Hours: Yes
Contribution to Project:
Worked on data development and maintenance, case study interviewing and interview transcription and coding. Full support from this grant.

Name: Tang, Li
Worked for more than 160 Hours: Yes
Contribution to Project:
Bibliometric data analysis. Support from this project.

Name: Horseley, Travis
Worked for more than 160 Hours: No
Contribution to Project:
Data entry, references, computer graphics.

Undergraduate Student

Name: Campbell, Audrey

Worked for more than 160 Hours: No

Contribution to Project:

Data entry and cleaning, spreadsheets and other data management functions.

Technician, Programmer

Other Participant

Research Experience for Undergraduates

Organizational Partners

Other Collaborators or Contacts

Activities and Findings

Research and Education Activities:

(1) Bibliometric analysis of 3500 publications from each of the 15 non-societal NSECs and 75,000 articles that cited these NSECs articles (2) content analysis of annual reports of these NSECs (3) extraction and keyword analysis of patent applications and grants using natural language programming of patent titles (4) telephone interviews with center directors (5) on-site visits at three of the NSECs.

Findings: (See PDF version submitted by PI at the end of the report)

Training and Development:

This project provided opportunities for students to develop network analysis capabilities with large scale datasets. The research assistants developed their skills in the gathering and analysis of publications for bibliometrics and the content analysis of reports and interview data for qualitative case studies.

Outreach Activities:

The results of this project were presented at the 2010 NSF Nanoscale Science and Engineering Grantees Conference, December 6-8, 2010 in Arlington, Virginia. Two executive summaries of main findings were produced, one at the half way point of the project and one at the end, for distribution to policy makers

Journal Publications

Books or Other One-time Publications

Web/Internet Site

Other Specific Products

Contributions

Contributions within Discipline:

Our contribution to the discipline of research evaluation is both substantive and methodological. Substantively, we are able to show the mechanisms by which research centers in the area of nanotechnology generate outcomes and impacts that are multidimensional in nature. These results are important for the learning component of program management which this evaluative research project aims to contribute to. Research centers are a major R&D program implementation tool in contemporary science and technology policy. Understanding the causal mechanisms by which they generate outcomes and impacts is of critical public policy importance. On the methodological front, the research design applies a novel mixed methods approach of quantitative followed by qualitative design to elucidate the mechanisms mentioned above. The preliminary findings reported above show the promise of the approach.

Contributions to Other Disciplines:

Our project also contributes to the general area of science and technology studies with a more detailed understanding of the organizations and institutions of research and their interaction with other sectors, such as industry and government. The manner in which they produce benefits for a diverse set of constituencies is also determined with our approach. These constituencies are the rest of the scientific community who uses their results, the higher education community that update curricula and teaching approaches based on centers??? work, the pre-university education constituencies that the centers serve with professional development programs, experiences for middles school and high school students, the public at large in their need for scientific literacy served through museum exhibits and open houses, and the policy-making community who learns from the experience for future policy and program design and implementation. The specific focus of the centers??? work also serves needs of specific industries by providing new approaches and inventions that can lead to new products and of patients suffering certain illnesses that scientific contributions in nano-bio technology are creating new diagnostic tools and treatments for. Our work contributes to the understanding of how these results are generated from R&D arrangements such as the NSECs.

Contributions to Human Resource Development:

The direct effect is on the doctoral student working on the project. Secondly, other students in adjacent activities participate in the weekly project meetings and are encouraged to apply this experience to their own assignments and projects. The project experience is fed into the curriculum development of research methods courses and emerging technology analysis courses taught by faculty who participate in this project. Our project continues to prove to be a fertile training ground for educating future science policy professionals. These students are developing a unique set of skills that they will subsequently disseminate to the S&T evaluation community. We actively encourage our students to produce original research and provide them with opportunities to present this research through peer assessments, conferences, and publication. Our project team is quite diverse, including women faculty and doctoral students, foreign nationals among the faculty researchers.

Contributions to Resources for Research and Education:

No new infrastructural resources were created in this project.

Contributions Beyond Science and Engineering:

The main broader contribution of this project is the improvement of policy and efficient use of public resources in the pursuit of multidimensional outcomes from R&D activities.
The results are available for the development of the US national policy on nanotechnology. The results of this project directly inform decision making for the next stage of nanotechnology support in the country.

Conference Proceedings

Categories for which nothing is reported:

Organizational Partners

Any Journal

Any Book

Any Web/Internet Site

Any Product

Any Conference

Assessment of Fifteen Nanotechnology Science and Engineering Centers' (NSECs) Outcomes and Impacts: Their contribution to NNI Objectives and Goals

Final Report

March 2011

Award 0955089

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The nanotechnology science and engineering centers (NSECs) program funded by NSF plays a key role in enabling the United States to keep its leadership in this critical area of science and engineering. In this project, we analyzed the outcomes and impacts of fifteen centers in the NSF NSEC program that focus on natural and biological research topics. Two centers specializing in social science implications of nanotechnology were not included since members of the project team are affiliated with them.

This assessment was conducted using a combined quantitative and qualitative methodology using data from center annual reports, NSF provided data summaries, reverse site visit presentations, interviews with center PIs, publication data from the Web of Science and field level data previously developed by our team.

A central finding of this project is that *the NSF NSEC program has contributed to the realization of the four goals of the National Nanotechnology Initiative (NNI)*, namely,

1. Advance world-class nanotechnology R&D
2. Foster the transfer of new technologies into products for commercial and public benefit
3. Develop and sustain educational resources, a skilled workforce, and supporting infrastructure to advance nanotechnology
4. Support responsible development of nanotechnology

Having said that, the importance of a program such as this one lies in the specifics of how this contribution to national goals was made because of the lessons they provide for future policy and program design. NSECs have demonstrated great and strategic flexibility in evolving as the field has evolved, addressing multiple goals at the same time, influencing the organization of science at their schools, and reorienting a significant amount of support around key early career investigators who have since reached the top of their subfield in new areas of nanotechnology.

The key findings of our assessment are as follows:

1. **The performance of research by the centers ranks at the top of the global nanotechnology field**

Using standard measures from bibliometric analysis, the centers show high publication productivity and exponential growth of citations by others throughout the existence of the program (slide 2). Compared to the entire field of nanotechnology, the median number of citations to papers from NSECs approximately quadruples the median number of citations to the corresponding cohort of the entire field of nanotechnology at the global level (slide 3 for 2002 cohort). This means that the collection of papers coming from NSECs rank in the very top tier of the field in terms of the citations by others. For example, the top 20 of 128 papers published in 2002 ranked in the top 566 papers among the 35 thousand nanotechnology papers published that year. In other words, roughly the top 20% of NSEC papers ranked in the top 2% of their cohort. Other years show similar results.

2. **The influence of the centers via collaboration and citation extends to all states in US and many countries overseas and grew over time.**

The activities of the NSEC program have a broad influence on the landscape of nanotechnology research nationally and globally. On the one hand, the high importance of what is published measured by the number of citations translates into a wide geographical distribution of authors citing NSEC papers (slides 4 and 5). On the other hand, there is a direct influence on work by others through a network of collaborations reflected in co-authorship of papers. NSEC authors publish with researchers in almost all states of the US and are cited by researchers in all states (slide 5). A similar picture emerges at the global level (slide4).

3. **The NSEC program has become a key research resource for industry**

The links of NSEC research with industry are multidimensional. First, research activities have led to the creation of many new companies to develop the commercial applications of those results. Several centers are creating new spin-off companies at a rate of more than one company a year and have been viewed as a signal for venture investment, as shown by the $80 million in venture capital for one center spinoff. Obviously, the rapid commercial viability of research results is not universal across topics in a field so the differences across centers are mostly a function of their specialty. However, this program has shown extremely high productivity for the direct path to commercial applications. Second, NSECs have very fruitful relations with established companies with interest or experience in nanotechnology. We were able to document the direct research collaboration with industry through co-authorship of papers. These sorts of collaborations reflect quite intense interactions. On average, over the decade of existence of the NSEC program, 10% of all publications had industry co-authors and a total of 146 different firms were represented in those papers (slide 6). Third, many interactions between the center researchers and industry transcend the scope of what the NSEC program will count as part of its sponsored activities. So most of what is actually reported is an undercount of the commercial consequences of this links. Collaborative projects and further developments of NSEC research emerge out of these interactions. The nature of these interactions has created an interdependence of academic NSEC research and industry nanotechnology work that is reflected in the pattern of these relations (slides 7 to 10). They are clearly part of the core capabilities of the country in nanotechnology both academically and commercially.

4. **Centers have created highly innovative educational programs and experiences at all levels**

All the centers show great creativity in the design of educational programs for all constituencies: graduate, undergraduate, school science teachers (especially high school or middle school), K-12 students and, through partnerships with science museums, the public at large. From our experience as analysts of centers including past NSF and other agency programs, it is interesting to observe how these activities are now much more integrated into the core activities of the center than was the case in the past. They have concluded that standardized programs of a “one-size-fits-all” nature are generally not effective. And in every case there is high participation of center researchers in programs and activities. In addition, many centers consider not just how to reach local K-12 and university students with new nanotechnology courses, but how to expand their educational capabilities through new web-based applications, video, and gaming approaches. The programs are designed by center members and reflect experimentation and learning leading to a product adjusted to the needs of the relevant audiences and generally seen to be carried out with significant enthusiasm.

Virtually all centers have a very healthy combination of senior and junior faculty, male and female students and faculty and members from majority and minority backgrounds. This environment is the result of deliberate recruitment policies and of mentoring and seed funding practices that encourage all participants to grow to their fullest potential. Their human resource development strategy allowed by the nature of centers enables rapid progress career trajectories that are much less frequent and/or require longer timeframes through the individual research grant method.

5. **Most of the benefits of the program are not sustainable without a coordinated center program providing core funding**

The center mechanism for supporting research in this field has some unique features that have proven to be the right one (slides 11 to 13). First, there is a unique incentive to go deeply across disciplinary boundaries by reducing significantly the transaction costs that doing cross-disciplinary work entails. The center program operates as a portfolio in the field and allows teams of researchers to focus on complex problem areas that require development of new competencies. The center mechanism reduces the cost and the risk for researchers to engage in such development. Second, the centers provide a unique research experience for graduate students who are the future leaders of the field. They have access to rich and diverse infrastructure that enables them to take on more interesting but risky topics. They are exposed to a greater number of high quality scientific and industry contacts, a key path for transfer of knowledge. Third, they accelerate the development of young faculty due to the diversity and depth of mentoring opportunities. Finally, the unique infrastructure of research labs and instruments is developed leveraging core center funding. Much of this may go to waste or be stunted in its development without a coordinated center program.

NSEC Outcomes and Impacts: Final Report

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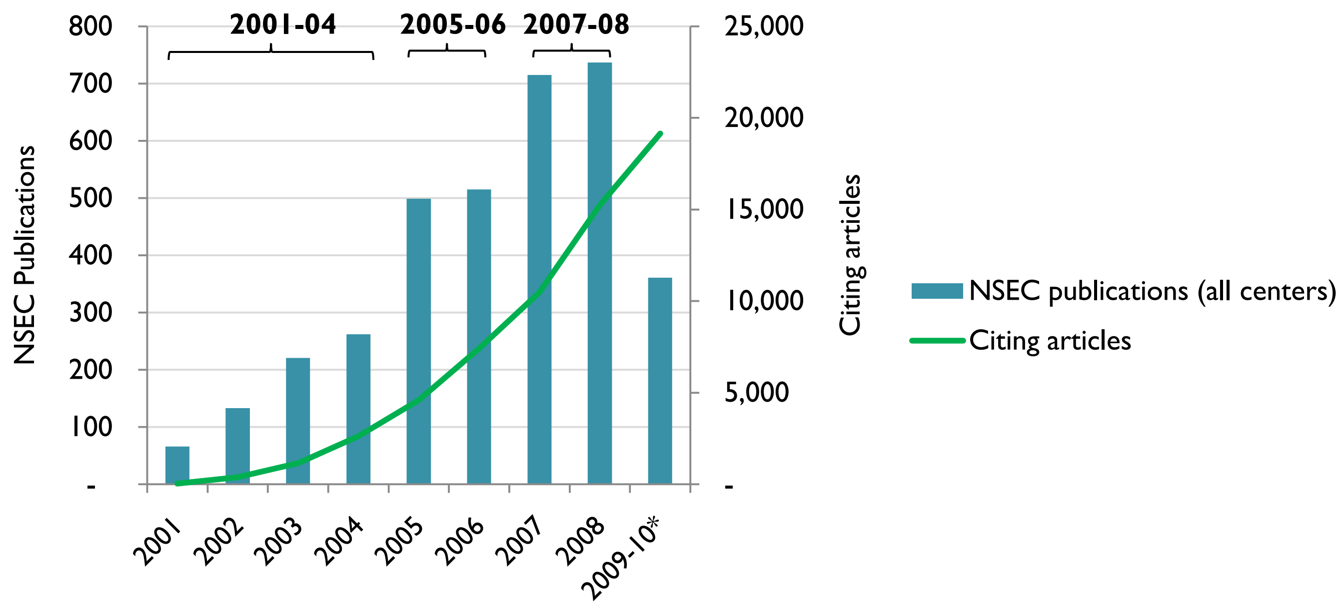
Project: Assessment of 15 Nanotechnology Science and Engineering Centers' (NSECs): Outcomes and Impacts: Their Contribution to NNI Objectives and Goals, NSF 0955089.

NSEC publication activity grows in three waves



	2001	2002	2003	2004	2005	2006	2007	2008	2009-10*	2001-10*
NSEC publications (all centers)	66	133	221	262	499	515	715	737	361	3,870
▪ *Annual change*		*102%*	*66%*	*19%*	*90%*	*3%*	*39%*	*3%*	*-51%*	*34%*
Citing articles	48	391	1,164	2,619	4,595	7,415	10,469	15,243	19,149	94,484
▪ *Annual change*		*715%*	*198%*	*125%*	*75%*	*61%*	*41%*	*46%*	*26%*	*12%*

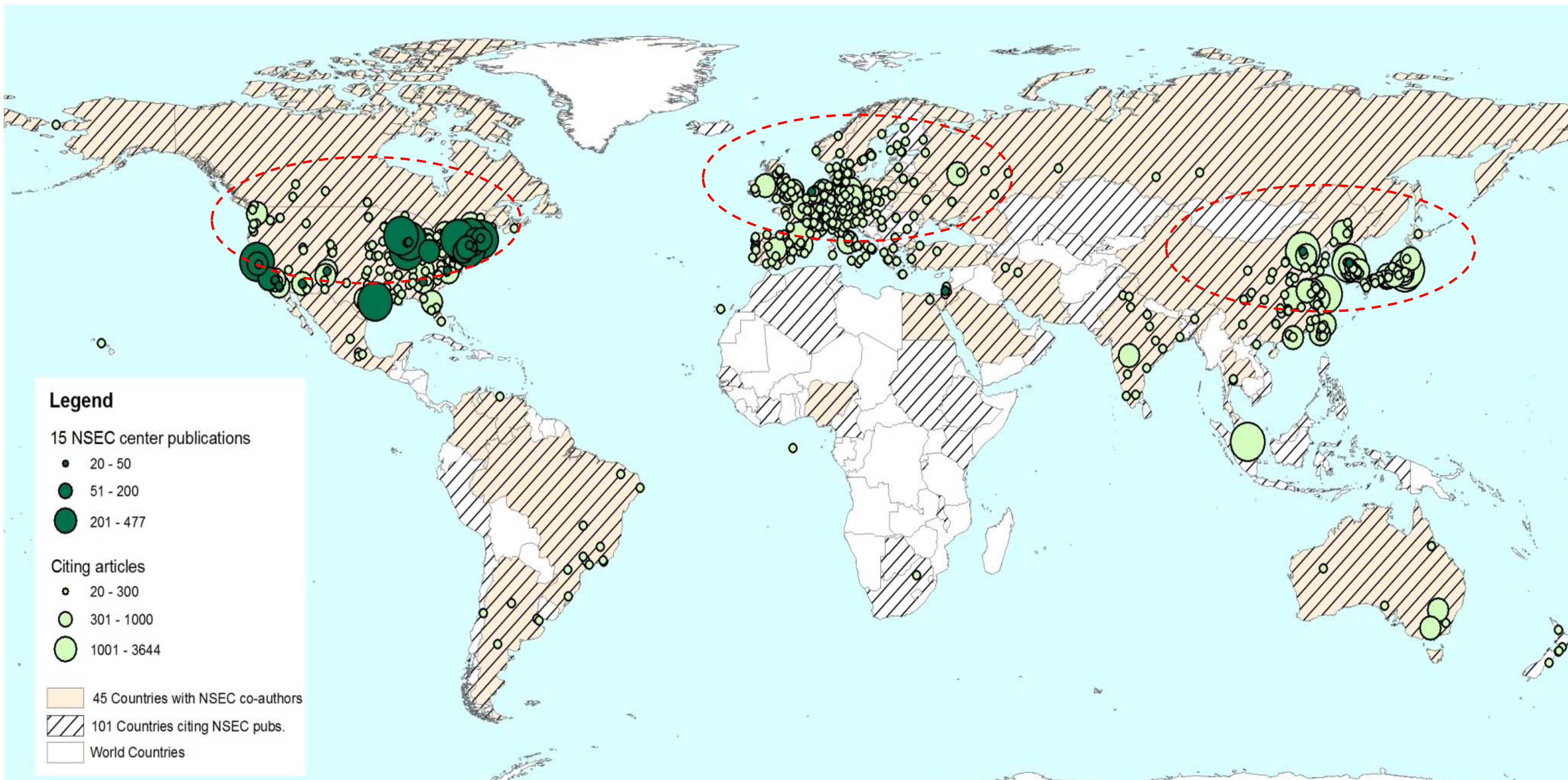
Notes: *Publication data not reported by all NSEC centers at time of data collection and the last year was incomplete in the databases; last column reports average annual change for rows with change data.
Source: ISI-WoS publication data based on NSEC annual reports by center.

Comparative Impact of NSEC Papers (Citations Cohort 2002)

	2002	2003	2004	2005	2006	2007	2008	2009
N_Mean	1.20	9.06	21.32	36.92	51.75	67.13	85.15	101.80
N_Med	0	3	8.5	16	20.5	25.5	30.5	36.5
N_Max	19	88	196	400	585	807	1063	1330
C_Mean	0.28	2.32	5.30	8.83	12.10	15.36	18.79	21.92
C_Med	0	1	2	4	6	7	8	9
C_Max	50	153	340	661	1053	1499	2042	2587

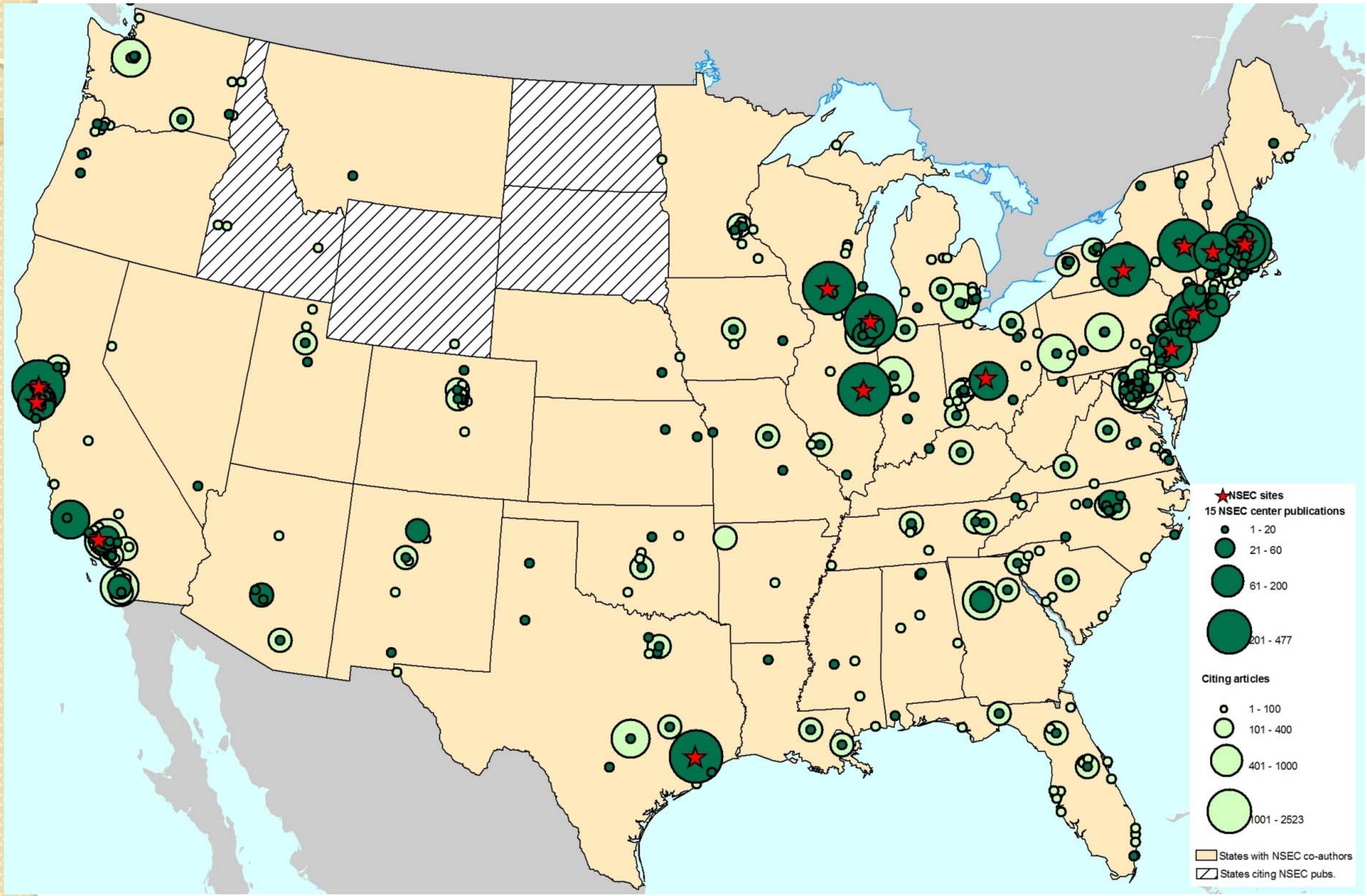
NSEC papers appear to have higher impact measured by citations: median and mean citations grow faster than the cohort with window length

Wide geographic spread of NSEC research with concentration in specific locations/regions



Note: Number of NSEC publications from 2001-2010 = 3509; number of citing publications = 75335. Citing publications, 2001-2010 exclude all NSEC publications.

Co-authoring extends beyond the NSECs to nearly all US states



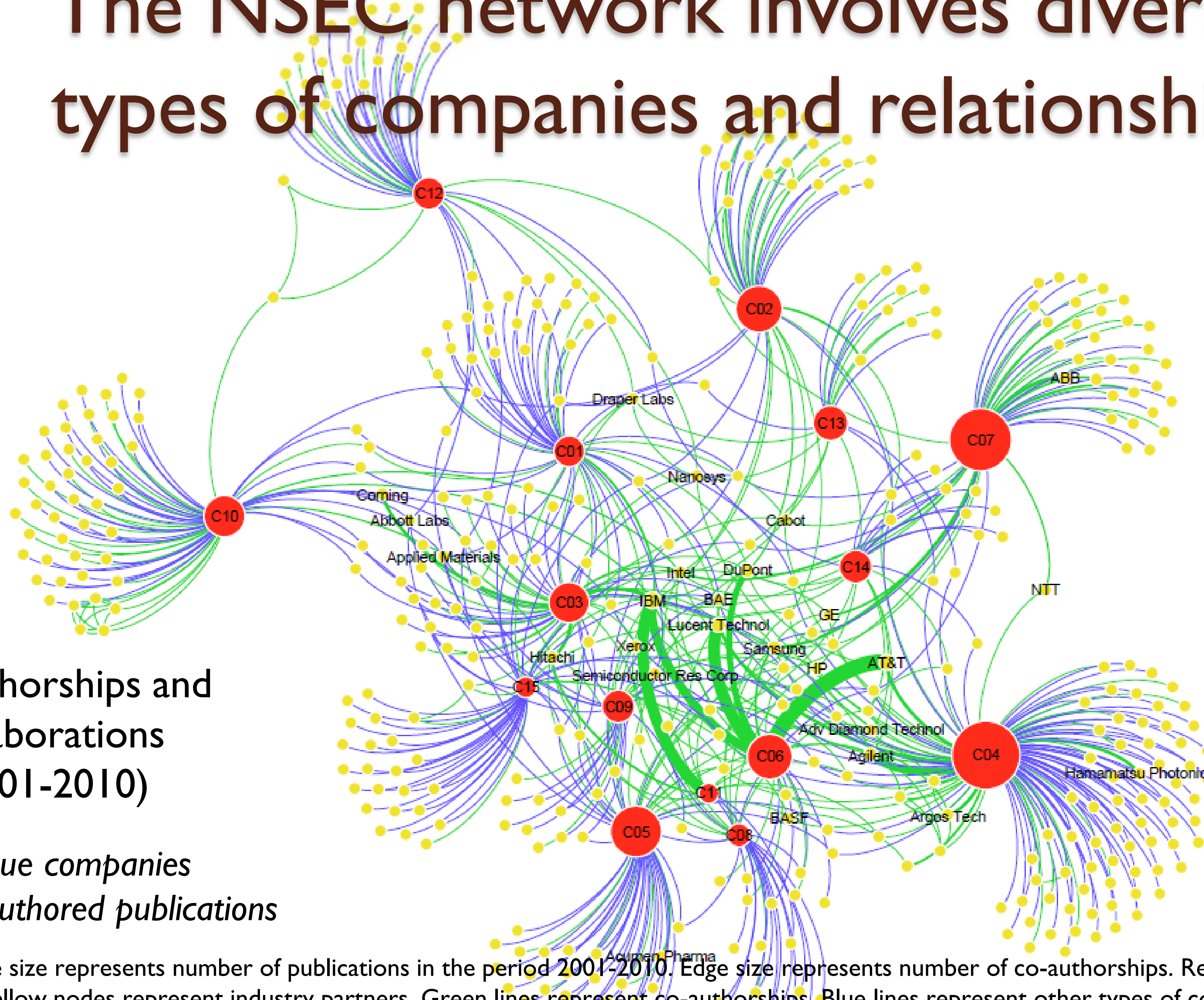
One out of 10 NSEC publications has an industry co-author

	2001	2002	2003	2004	2005	2006	2007	2008	2009-10*	2001-10*
NSEC centers with publications	3	6	6	13	13	15	15	15	13	15
NSEC publications (all centers)	66	133	221	262	499	515	715	737	361	3,509
NSEC pubs. co-auth. with industry	12	13	16	17	35	52	76	65	34	360
▪ *Annual change*		*8%*	*23%*	*6%*	*106%*	*49%*	*46%*	*-14%*	*-48%*	*22%*
▪ *Share industry co-auth / all pubs.*	18%	10%	7%	6%	7%	10%	11%	9%	9%	10%
Unique co-author firms	11	13	9	16	31	29	50	43	22	146
▪ *Annual change*		*18%*	*-31%*	*78%*	*94%*	*-6%*	*72%*	*-14%*	*-49%*	*20%*

Total unique firms co-authoring articles with NSEC (2001-2010): 146
Total unique firms maintaining other types of collaborations with NSEC (as of 2010): 275**

Notes: * Publication data for this period not reported by all NSEC centers at time of data collection and the last year was incomplete in the databases; last column reports average annual change for rows with change data.
**The type of collaborations are not specified by centers (only number of industry partners was provided).
Source: ISI-WoS publication data based on NSEC annual reports by center and lists of industry partners provided by NSEC centers.

The NSEC network involves diverse types of companies and relationships



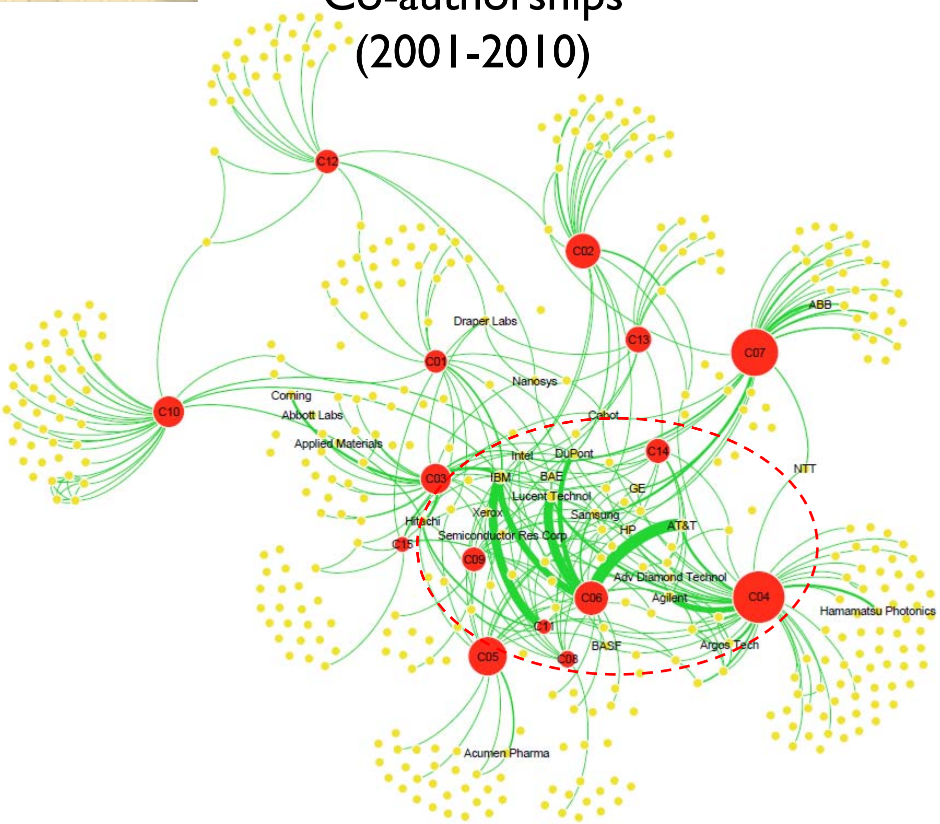
Co-authorships and collaborations (2001-2010)

421 unique companies
360 co-authored publications

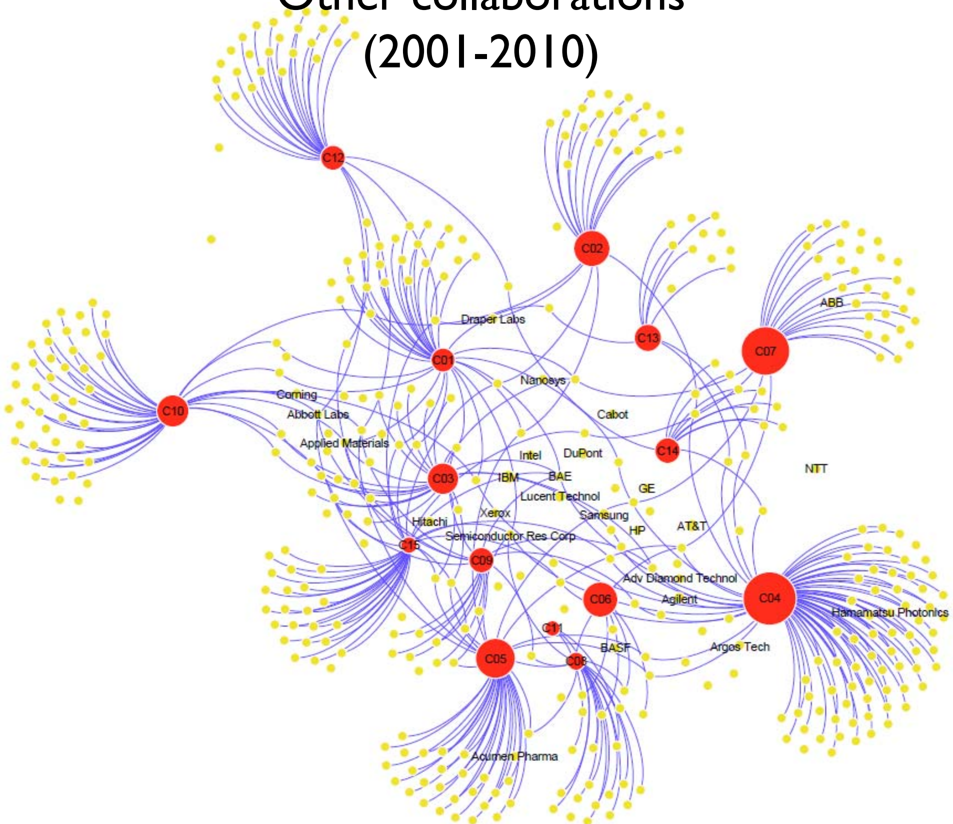
Notes: Node size represents number of publications in the period 2001-2010. Edge size represents number of co-authorships. Red nodes represent 15 NSECs. Yellow nodes represent industry partners. Green lines represent co-authorships. Blue lines represent other types of collaborations. Labels are shown only for NSEC centers (anonymized) and top-25 industry partners according to number of co-authored publications.
Source: Analysis based on list of industry partners provided by NSEC centers as of 2010 and publications in ISI-WoS database for period 2001-2010.

Separating co-authorship network from general links shows diversity of interactions

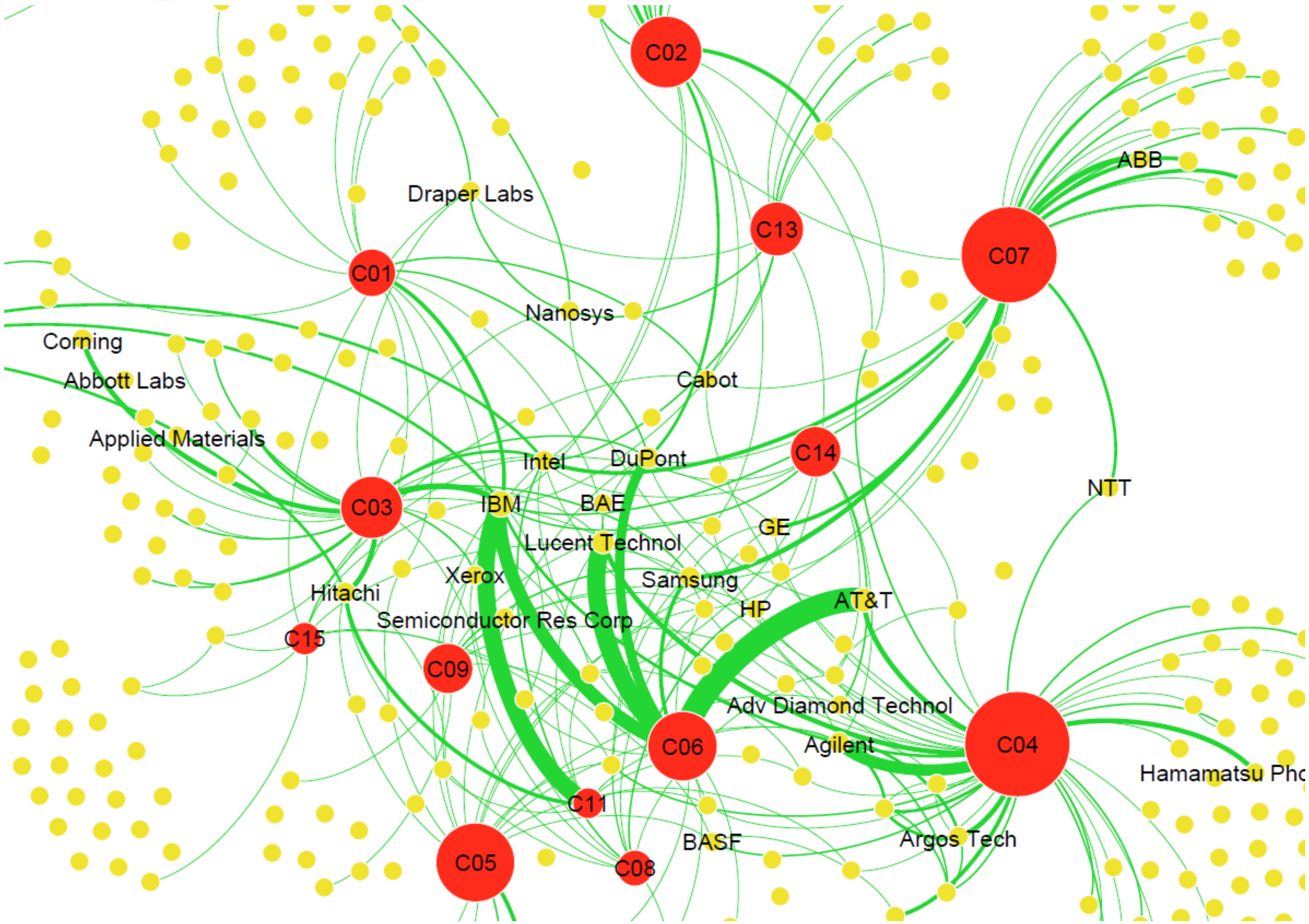
Co-authorships (2001-2010)



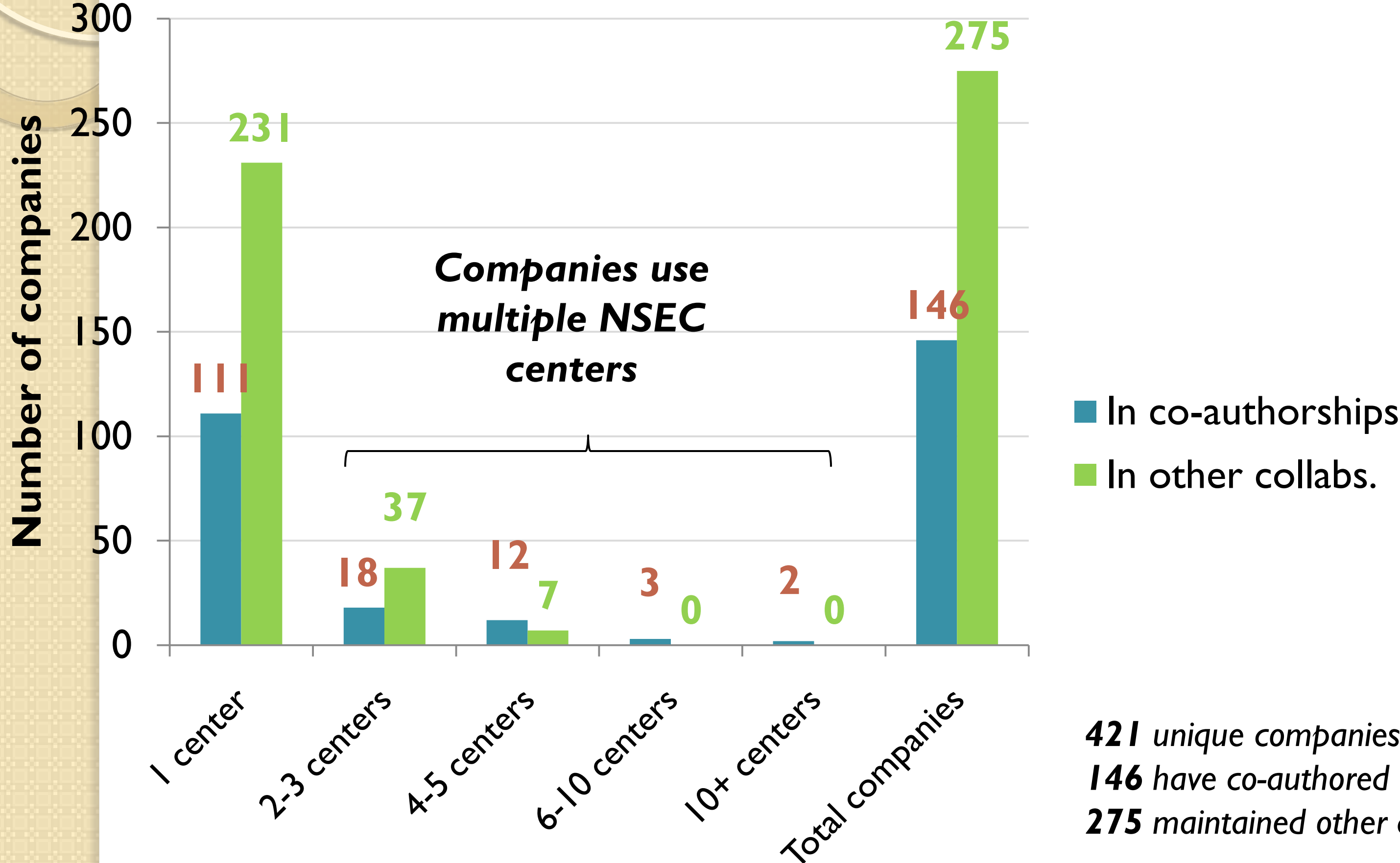
Other collaborations (2001-2010)



Main industry co-authors are a few large companies



Some companies use the NSECs as a network



421 *unique companies (2001-2010)*
146 *have co-authored with NSEC centers*
275 *maintained other collaborations*

Implications for Center Policy

- NSEC publication growth rate indicates rapid take-off by new centers.
- Co-authorship with industry indicates deep integration of collaborative activities.
- A core industry sector relies on NSECs as a network of centers.
- NSEC mechanism allows for greater involvement of authors over time in diverse locations.
- NSEC research involves some foundational as well as some emerging (and some maturing) topical areas.
- NSECs work in multiple disciplines and their citation influence involves many more disciplines (especially in Biotechnology related fields).

The Case for Centers

- Unique incentive to go deeply across disciplinary boundaries
  - Significantly reduced cross-disciplinary transaction costs
- Unique research experience for graduate students
  - Rich and diverse research infrastructure enables more risk taking
  - Exposure to greater number of high quality scientific contacts
  - Exposure to unique industry contacts
- Accelerator of promising young researcher development
  - Center as recruiting tool of top talent
  - Diverse mentoring opportunities for rapid career development
- Unique infrastructure possibilities
  - Leverage of resources for shared new facilities
  - Design of new unique instruments and experimental arrangements

Some Program Challenges

- Some scientific contributions are difficult to explain to the lay public
  - Important for long term support of the enterprise
- The variety of time constants for developing commercial potential should be factored into the center program
- The special benefits for development of faculty and graduate students should be scaled up to reach the rest of the university community
- The pre- and extra- university education efforts are dependent on the center program and are difficult to institutionalize without it.
  - Their sustainability should be a program concern
- Similar sustainability issue is raised by specialized infrastructure that may go to waste if centers are discontinued
- Societal impacts are not well integrated and seem distant as an interdisciplinary challenge