

Infrastructure Planning and Implementation for Transformative and Incremental Research

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A very important element in the planning for research infrastructure is the predictability of infrastructure needs. Research is a creative activity—doing things that have not been done before. Capturing the needs of those who are doing something that has not been done before is a problematic issue, with success depending heavily on the nature of the research being done (NSF. “Academic Research Infrastructure Program: Recovery and Reinvestment (ARI-R2); NSF. FAQs Regarding Academic Infrastructure-Recovery and Reinvestment (ARI-R2). Program Solicitation. NSF 009-562 Part1.www.nsf.gov/pubs/2009/nsf0905.1/nsf09051.jsp). In this paper, I will examine the issues that affect our thinking and action regarding transformative research (i.e. world-changing, very high-impact research) as opposed to more incremental research (i.e., taking the next step beyond what is already known) (NSF. Introduction to Transformative Research. nsf.gov/about/transformative_research/definition.jsp). This complicated dynamic plays out in institutional settings and in higher education broadly as well as other kinds of research venues (e.g., the business world or national labs).

The Idea of Infrastructure

“Research infrastructure” must be defined broadly, including not just STEM research, but also professions, arts and humanities, social science, and more. This paper considers “research” to be creative activity in the broadest sense, and the infrastructure issues have a great deal in common across the many areas of creativity. (For two good examples of the breadth of infrastructure issues see Gisele Yasmeeen, 2015; UMBC, “Research Infrastructure – Center for Innovation, Research, and Creativity in the Arts”.) So, while infrastructure is most commonly thought of as labs, major technology such as a radio-astronomy center, or a nuclear reactor, in this paper it may be a theater venue, a facility to bring together an in-

terdisciplinary group to address fundamental changes in the future of media, or it might include a major fine arts collection or a unique collection of fossils in a museum.

From this perspective, infrastructure includes all of the many resources necessary to support successful research/creative activity. Thus, infrastructure would include personnel—e.g., staff who provide grant support, logistics, lab work, compliance process, stage design, and library circulation. In academic institutions, of course, faculty are a major infrastructure resource (this issue is complex and will be addressed below). Students provide “staff” work in many areas (e.g., in labs, performance venues, media). Facilities (i.e., buildings, lab equipment,

museum collections, and libraries) are core to infrastructure, as are the many IT functions (e.g., communication, data archiving, computational capabilities, and access to prior research results). Many management processes are critical, including a long list of personnel processes (e.g., hiring, P&T, performance evaluations) and compliance management (e.g., IRB, conflict of interest management, export control).

A critical infrastructure element is the network of relationships on which institutional collaborations can be built (e.g., national labs, corporate partners, universities). Similarly, having an effective network of relationships with federal funding sources is critical for certain kinds of research. For example, we need relationships with a broad range of federal agencies, not just NSF and NIH, but also Defense, Homeland Security, Agriculture, Education, and others. This is critical, since most federal funding comes from agencies who do not fund by traditional peer reviewed proposals. And, along this same line, relations with beltway bandits, lobbyists, and other “highly connected” people in Washington, D.C. are an important element of infrastructure. And then, for public institutions, there is the funding from states and/or other governmental sources. Of course much research is funded by the institution or, if grant funded, much is significantly subsidized.

A key element of infrastructure planning is that all of these elements intersect with others. And to make matters even more complex, there are widely varying needs across disciplines, professional schools, in basic versus applied research, and discipline-based versus interdiscipli-

nary or multidisciplinary research. In addition, there is the nature of the institution (e.g., the strengths that it’s recognized for, the brand), and the nature and amount of its funding (e.g., public or private, degree of state support, endowment, fundraising, etc.). And finally there is the complication that research/creative activity is about creating new “knowledge” (in the broadest possible sense of the word), and the content of research and needed infrastructure is constantly changing due to changes brought about by the research itself.

The complexity of this broad perspective on research infrastructure is made even more daunting by the fact that higher education is in a time of great volatility in many dimensions: state funding, demographic changes, international competition, political interest and intervention at all levels, decreases in federal grant funding, and a significant loss of confidence/respect for higher education in the general public—a critical issue for political impact.

Transformative and Incremental Research

An interesting conundrum for Universities is to think about the relative value, priority, and feasibility of transformative, very high-impact research compared with more incremental work that extends what is already known. NSF defines “transformative” research as follows:

Transformative research involves ideas, discoveries, or tools that radically change our understanding of an important existing scientific or engineering concept or educational practice or leads to the creation of a new

paradigm or field of sciences, engineering, or education. Such research challenges current understanding or provides pathways to new frontiers (NSF, “Definition of Transformative Research”).

This definition could be extended to other than STEM areas, including humanities, social sciences, professions, biomedical research, performing arts, and much more (Wikipedia “Transformative Research”). It is important to note that the idea of “transformative” research is often seen as converging with what is called “high impact research” (American University, 2015), and that the latter is commonly seen more as applied than basic research (Economic and Social Research Council).

There is, of course, a continuum between extremely “out of the box” transformative research and very structured incremental research. Research at both ends of the continuum is extremely important—but important in different ways. The biggest, world-changing results lead to more incremental research, often very important at both ends of the basic and applied research continuum. As the NSF paper on transformative research notes: “History shows that it is difficult to predict which research projects will result in transformative results before the research is conducted and the scientific community has assimilated the findings.” (NSF. “Transformative Research: Challenges of Identifying Potentially Transformative Research” p. 1). This assimilation may take decades (Sabine Hossenfelder, blog post, BackReaction.2012, p. 1). On the other hand, very high impact, ground-breaking outcomes

can arise serendipitously from surprise results on more structured incremental research.

Transformative research generally builds on a different mindset than more incremental work. Moreover, the incentives and disincentives that researchers encounter are profound, given the differences in predictability, outcomes, and the time frame (we will return to these issues in different contexts). Long-term collaborative relations with external entities such as national labs, corporate partners, or other universities tend to be more common for the more transformative, long-term research. But many infrastructure issues such as facilities, a broad range of institutional support (staff, compliance) are pretty much the same for both transformative and incremental work. From the standpoint of institutional stature, the transformative results generally bring the most recognition and honor. That said, many researchers, political constituents, and others—especially those on the applied research end—are more interested in results of immediate practical significance, whether in STEM areas, social sciences, humanities, professions, or arts. In fact, as noted above, this “practical” or “applied” outcome is how many would define “high impact” research. Clearly, a balance must be defined in institutional mission, planning, and broader campus culture, which in turn need to be aligned with critical elements of the campus environment such as incentive/disincentive structures (e.g., P&T), physical infrastructure, staff, and potential external collaborations.

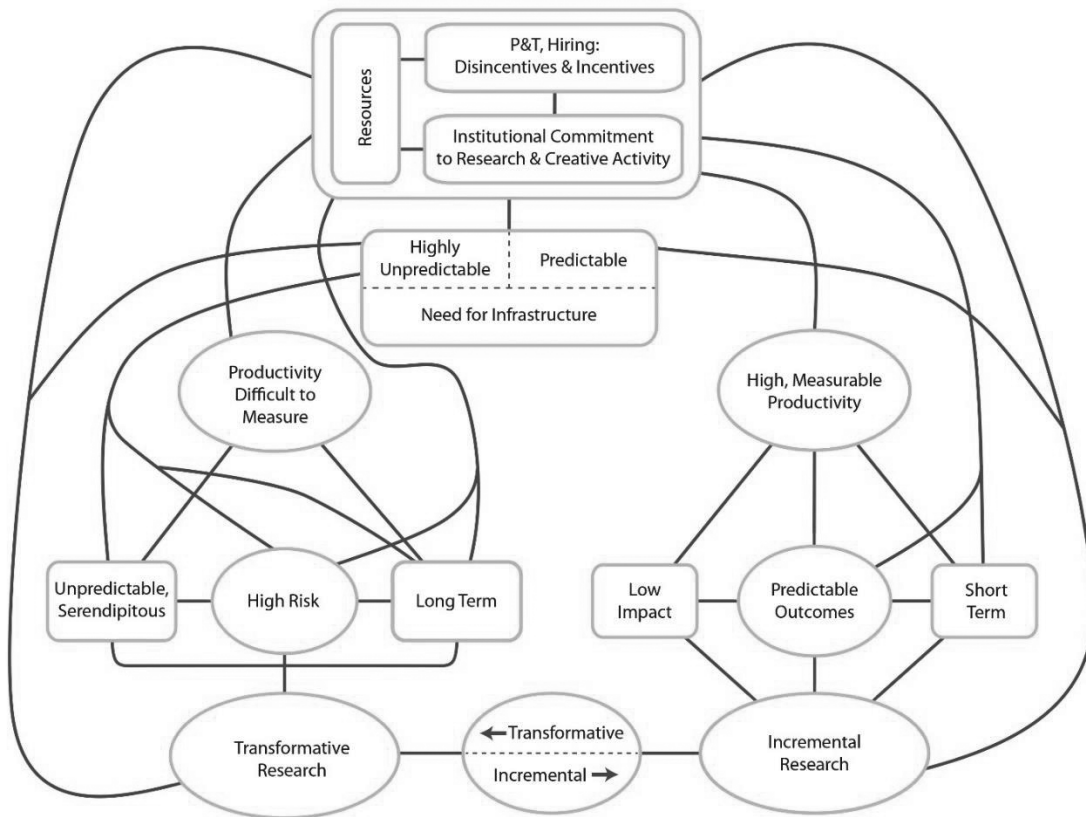
How it All Fits Together In the Perspective of Infrastructure

Figure 1 provides a simplistic, though still complicated, picture of the dynamics underlying the complexity of the infrastructure needs and the research priorities (transformative or incremental) of an institution.

One can start from either the top or the bottom of this figure, but here we will start from the bottom. The most important observations are that Transformative Research is extremely “high risk” with respect to the probability of achiev-

ing a positive outcome, while incremental research is far more predictable, both in implementation and in results. As noted on page 2, there is a continuum between transformative and incremental research—elements to the left of the middle in Figure 1 leaning toward transformative research, and to the right leaning toward incremental research. This continuum has a complicated set of implications for the rest of the analysis. It is important to note that some transformative research is extraordinarily demanding for infrastructure (e.g., facilities, instrumentation,

Figure 1. Institutional Implications of Transformative and Incremental Research



staff), while other work may simply be done in a researcher's existing lab or performance venue without additional resources.

Returning to Figure 1, on the transformative side, "high risk" implies both highly unpredictable, even serendipitous, and very long-term outcomes (NSF, "Challenges of Identifying Potentially Transformative Research"). Incremental research, on the other hand, suggests more predictable and short-term outcomes, though at the "incremental" end of the continuum, much lower impact. The idea of "productivity," which is central to accountability, setting priorities, and many other issues, is highly problematic on the "transformative" side, since it is very difficult to measure something that has never been done before and often challenges what is known. On the "incremental" side it is fairly predictable and measurable, since it is building on what is already known.

So, the question is, how does all of this play out from the perspective of research infrastructure? This raises a new dimension of complexity, since the broad campus culture of universities comes into play, including such things as hiring, fiscal resources, and priorities. In addition, there is the influence of constituencies as diverse as political, donor, trustee, students, and parents, as well as corporate and community elements, many of whom have conflicting interests. Some of the most critical effects on research arise from the incentives and disincentives posed by the promotion and tenure (P&T) and hiring processes. For associate and especially assistant professors, who

will be facing promotion and tenure hurdles: P&T, as practiced in most institutions, provides a strong disincentive for pursuing long-term, unpredictable research projects (Foster 2016). Since the likely long-term projects would not provide the kind of productivity needed for promotion or tenure, junior faculty are likely to go with more structured incremental research, which is more likely to produce the necessary publications, citations, and other elements of productivity needed for tenure or promotion within the probationary period. When it comes to infrastructure, the institution is not likely to invest significantly in a junior faculty member's transformative project, given that the researcher is unlikely to remain at the university—the likely case being that he/she won't receive tenure or promotion, thus making the infrastructure investment extremely risky.

Even full professors with tenure face significant disincentives for undertaking research toward the transformative end of the continuum, given that outcomes are extremely difficult to define and to present as credible, and "selling" the project to the institution or to a funding agency is at best difficult. A multi-year demanding project is likely to mean few publications or other relevant kinds of productivity (depending on the discipline, profession, etc.), thus compromising the researcher's status, and compromising his/her ability to write credible grant proposals, sell the project to the university for funding, or otherwise find facilities, equipment, and other resources needed to move the project forward.

Looking at these issues from the other side: there are strong incentives for the University to encourage short-term, more predictable incremental research, for which institutional funding can be allocated with a reasonable degree of risk, for which funding agencies are more likely to be positive and award grants, and which will result in research productivity (e.g., grants, publications, citations) that affect rankings for the institution and recognition for the researcher. From the infrastructure point of view, the needed resources are likely to be mitigated by grants, and the institutional capacity for funding infrastructure needs will be assessable such that priorities can be assigned based on somewhat predictable needs and outcomes.

If the institution's capacity (people, facilities, necessary support processes) is adequate to provide sound support for a wide range and large amount of incremental research without a significant amount of flexible funds for a costly, risky, high-impact, unpredictable project, it is unlikely that transformative projects will get high priority. Other paths may exist with modest institutional investment—e.g., funding from a major donor, foundation, or governmental agency with a special interest in the area of the project—but receiving such funding would require other kinds of resources in development, government relations, and corporate relations. Corporate collaboration or funding may be another path.

For an institution with a very large resource base, the situation is, of course, very different with respect to its ability to provide substantial funding. Moreover, it is such institutions who have the broad, effective networks of relations with

wealthy donors, potential corporate collaborators, and with federal agencies that provide the majority of federal research funding through processes other than traditional peer-reviewed grants from NIH and NSF. In addition, such institutions—generally elite research universities—hire senior faculty with tenure who are already well positioned in the academic world, who will not face the challenges and special incentives/disincentives of promotion and tenure, and who could be hired precisely to do very high-impact/transformational research that is already on the researcher's radar.

It is important here to return to the idea of the continuum between transformational and incremental research. The work somewhere in the middle of the transformational/incremental continuum tweaks all of the issues considered above. The outcomes may be much more predictable than the far-end transformational, thus making the project more likely to get grants, to bring outcomes in the short term, to perhaps have relatively short-term applications, and to fit into existing facilities. In addition, the shorter term, more predictable outcomes mitigate the threat to promotion and perhaps even tenure. Thus at the center of the continuum, the limits on traditional productivity are less than at the transformational end. But as compared to the incremental end, the "center" still poses disincentives through processes for promotion, compensation increases, and other benefits of high productivity—issues of significant consideration for researchers.

How It Plays Out in Different Academic Areas and Institutional Environments

Given the broad perspective on infrastructure outlined on pages 75-77, high-

level infrastructure is likely to be in areas of special institutional strength. This is an effective strategy for having not just incremental research done, but also presents potential for hiring high-quality faculty who are doing transformative work and who need special infrastructure. Such areas of strength may be historical accidents; some may be the outcome of a major gift from a wealthy donor with a passion for the area and a connection to the institution. Some strengths may come from an institutional investment (e.g., a bond-funded facility) in an area that is promising because of the location of the institution (e.g., new major corporate partners in the area or being embedded in a special environmental location). And there is the possibility of a faculty member, alumni, or external partner setting up a for-profit technical service provider that could serve researchers in a very broad area—even internationally. These are all, of course, randomly chosen examples to illustrate the range of influences on funding for high-level infrastructure.

Rather than attempt to frame a range of abstract examples, I will move on to several major facilities and other assets of the University of Missouri (MU) to try to enrich the argument. MU has some stunning strengths that are related strongly to unique facilities and other assets that support both the incremental research and provide the recruitment opportunities to bring to MU those interested in transformative research in these areas. Information on all of these initiatives can be found on the MU website (Missouri.edu).

There are, of course, significant differences across disciplines and different

funding strategies for dealing with infrastructure issues for transformative research. To explore some of these issues, I turn now to five different initiatives at the University of Missouri in Columbia. The five “approaches” are very different: a very strong nuclear reactor, a research center closely linked to the functions of the reactor, an interdisciplinary group that does research and clinical services for those on the autism spectrum, an institute that deals with research on the future of “journalism,” and a creative facility for independent senior living that has become a national model. In addition, I’ll briefly discuss a new initiative that was funded by a large gift from a passionate alum; its focus on issues of democracy, and it is anchored primarily in the humanities and social sciences.

MURR (MU Research Reactor). Perhaps the most impressive resource for transformative research at the University of Missouri is the Research Reactor, which was established approximately fifty years ago under the leadership of President Elmer Ellis. This was a vision of an iconic leader, based on the idea that nuclear research would be a central element of the U.S. future. The fiscal, regulatory, and research vision were all extremely complex and difficult to implement, but Ellis made it happen. A significant side-bar for this facility is that it is a major producer of radiopharmaceuticals, which produce significant revenue for the facility. Today MURR is the nation’s most powerful research reactor on a university campus.

International Institute of Nano and Molecular Medicine. Accordingly, MURR has become a significant research asset for MU—one of the most important

cases of which was its role in recruiting a faculty member who had a potentially transformative research agenda in Boron Chemistry (the end of which is still to be determined after approximately eight years at MU). The Institute was established as part of the recruitment of Fred Hawthorne, a member of the National Academy of Sciences and nominee for the Nobel Prize. The investment was significant: construction of a new building (several million dollars) near the reactor, and support for several support staff/faculty who came to MU with Dr. Hawthorne. There was no assurance that the Boron Chemistry research would produce the kind of targeted cancer treatment that was the vision for the program, but Dr. Hawthorne's status as a researcher and progress to date on the project were considered solid justification for the extremely significant investment. As is the case for all such transformative research, a successful outcome was not (and still is not) certain, but clinical trials are now underway. The point, of course, is not that it was a bad investment; rather, it was as good an investment as can be imagined for a truly transformative research initiative...an investment that would have been impossible without the earlier investment in a uniquely valuable resource—the research reactor.

Reynolds Journalism Institute. Another somewhat similar development, though in a field very different from nuclear science, is the foundation of the Reynolds Journalism Institute (RJI), which was built on the foundation of MU's School of Journalism—the oldest and arguably the most distinguished Journalism school in the world. In 2004 the Reynolds Foundation, established by

an extremely successful alum of the School of Journalism, provided a gift of \$31 million to establish the RJI. Major renovation of an iconic building next to the School of Journalism was done to provide perfect space for the journalism research enterprise. The launch of the Institute was extremely successful, and in 2012 the Reynolds Foundation provided another gift of \$30 million to endow the operations of the RJI. The RJI is now a powerful complement to the highly regarded School of Journalism, having supported the startup of several significant enterprises, supported research on the future of media (an extremely volatile and socially important element of American society) and a significant asset for the stature of the University of Missouri.

The Thompson Center for Autism and Neurodevelopmental Disorders. A very different initiative was establishment of the Thompson Center, which built on the rather scattered assets in many departments/colleges regarding Autism and other neurodevelopmental disorders—units as diverse as College of Education, Early Childhood Education (School of Human Environmental Sciences), Psychology, Pediatrics, Psychiatry, Clinical Psychology, Health Psychology (the department of the founding director), Sociology, Social Work, and even Athletics. With the support of the Thompson Center, the interdisciplinary community came together to create a nationally prominent center for research and clinical services for people on the autism spectrum. The Center has moved from a very marginal physical location to its own building near the MU Women's and Children's Hospital, and it is now

building a significant addition to its already impressive facility. As was the case for the RJI, the Thompson Center was driven by the passion and insight of an MU alum, but it was not built on the foundation of an integrated existing program or center in the area of Autism.

TigerPlace. TigerPlace is an innovative home for independent senior living. It was developed by the School of Nursing with collaborations from engineering and other disciplines as part of a broader project on aging in place. One of the distinguishing features is that it includes very sophisticated technologies for tracking the residents, detecting falls, and creating sophisticated longitudinal data bases on residents' patterns of life—a unique research asset. The technology was created jointly by Nursing and Engineering. The facility was built by Americare Corporation, a large healthcare company from Sikeston, MO, working closely with Nursing; today TigerPlace is owned and managed by Americare. It has received a great deal of notice nationally as a model for such facilities, and several very positive things have followed. One is creation of an affiliated Nursing Home facility, the Neighborhoods, which is located very close by. Marilyn Rantz, the leading nurse for the creation of TigerPlace was elected to the Institute of Medicine, and recently the Nursing School received a grant for more than \$20 million to develop facilities in the St. Louis area.

Kinder Institute on Constitutional Democracy. A very different kind of initiative is the Kinder Institute (formerly the Kinder Forum), which was given important momentum in 2016 when it re-

ceived a \$25 million gift to endow the operation of the center, which is focused on education and research on the U.S. Constitution and on American democracy in history, theory, and practice. The Institute was initially based in the History and Political Science departments, but it has incorporated faculty from other departments and is now a truly interdisciplinary center which has a physical home. The goal is for MU to become a national leader in research and education in the area of constitutional democracy, recruit prominent scholars, and support both research and educational activities. The Institute is new, and its mission is still somewhat unclear, but it builds on significant strengths at MU and has potential to support transformative research and educational practice. It has been driven significantly by the passion of Rich and Nancy Kinder and their strong relations with MU. Clearly, it is an initiative with significant potential to be far toward the transformative end of the continuum.

The question, now, is how these six “initiatives” relate to developing infrastructure for transformative research. First, all but one have had significant external funding for establishing the initiative. The one that was not externally funded was the International Institute of Nano and Molecular Medicine, for which a very significant institutional investment was made explicitly to bring a prominent internationally recognized researcher to campus to continue a potentially transformative research program—an investment that included building a new building near MURR to house the Institute. But what made the recruitment of Dr. Hawthorne possible was the presence

of a unique facility, MURR, and the interdisciplinary cluster of researchers working with the reactor on nano science, radiopharmaceuticals, and other activities related to his boron chemistry research.

From this perspective, MURR is a unique facility that has potential for supporting transformative research. It was not established with a specific research plan in place, though it has seen remarkable successes in research, radiopharmaceutical production, archaeometry, and much more. What is perhaps most surprising is that the campus has not developed a broad, coherent, interdisciplinary program in Nuclear Science and Engineering, though there are very significant strengths across campus, including the Nuclear Science and Engineering Program (a highly productive program of four engineers), radiochemistry, radiology, and a nuclear engineering group in the College of Engineering.

As noted earlier, the gift for the Reynolds Journalism Institute is building on a campus resource rather analogous to the reactor: the MU School of Journalism is internationally recognized as one of the most prominent journalism schools in the world. In this case, MU is building not on recruiting a world-prominent researcher with a particular on-going program, but is building on a distinguished, internationally recognized group of faculty known for being “out-front” in the incredibly volatile world of journalism. RJI has helped bring together researchers across campus with related interests (from policy studies, business, creative writing, communication studies, and much more) and has been an important factor in attracting new faculty to the School of Journalism and RJI. It is fair to

say that the RJI has already had very significant impact in the world of media, including research, start-up firms, and student experience. There is real progress across the continuum from incremental to genuine transformative research.

The Thompson Center was built on a substantial gift from alumni with a strong connection with the University of Missouri. The vision and passion for the Thompson Center stemmed from a family connection with autism. MU had significant assets (especially faculty), but they were scattered across the campus. Building on MU’s strong interdisciplinary culture, foundation of the Center brought this broad group together more formally, creating a center unlike other autism units across the country, the strong and broad interdisciplinary collaboration in research and clinical services for autistic children being especially unique. The potential is very strong, and the infrastructure (physical facilities, people, grants, and now nation-wide recognition) has significantly advanced the Center on the path to transformative research and clinical service.

TigerPlace has a very different kind of development. The “Aging in Place” concept was developed in the School of Nursing, and an institute was created that engaged a number of Missouri senior living institutions in providing an innovative kind of environment for seniors who were able to be “independent” but with very specific kinds of support. The idea of TigerPlace grew out of this senior living idea, with significant collaboration between the School of Nursing and the College of Engineering. As noted above, implementation of the idea was done in collaboration with Americare, a large

senior living corporation, which actually built TigerPlace and manages it, but very much driven by the concepts that came from Nursing and Engineering—a perfect model for corporate and university collaboration.

Finally, the Kinder Institute is a different kind of initiative, founded on several years of dialogue with the donor about the potential for an institute that would build on MU's strengths in Political Science, History, and the Humanities. The \$25 million gift to endow the Kinder Institute on Constitutional Democracy builds on significant strengths in social sciences and humanities, but also Law, Policy, and other areas. The mission is to support research and education on the U.S. Constitution and American democracy in history, theory, and practice. The Institute will be located in the iconic Jesse Hall. As Director Justin Dyer has said, it's important to have an actual physical home for the center where scholars and students from different parts of the campus can come together "all in one place." The funds will support faculty fellows, faculty hiring, program development, guest lecturers, and other activities that contribute to the stature and impact of the center's work. The Kinder Institute doesn't have an anchor like MURR or the Journalism School. More like the Thompson Center, it builds on significant strengths and brings them together in a way that provides potential for very high impact research. But the plan is new and is a work in progress.

Concluding Thoughts

All of the six initiatives described above have potential, five having moved far along the transformative research continuum. At least one of them is on a

direct, well-defined track to transformative cancer treatment. Closely related is an internationally valuable research resource, MURR, which is a critical foundation for the Hawthorne Center. Three of the other centers have already achieved significant national and international recognition: the Thompson Center, the RJI, and TigerPlace. It may be a little too far to claim that they have achieved "transformative" research results, but they are all quite a way down the continuum from incremental to transformative—well beyond the "center" as represented in Figure 1.

What is perhaps more important is the broad range of contributions these highly successful initiatives have produced. One is a combination of research and clinical services (i.e., the Thompson Center)—very significant contributions in both dimensions. One builds on an internationally famous journalism program to provide out-front research and education related to the extremely volatile world of media—a program with immense potential for strong influence in a critically important area of today's political, social, intellectual, and economic dynamics. One—TigerPlace—builds on dynamics in the extremely important area of healthcare and quality of life in a world where life expectancy has increased dramatically. The potential impact of this model of senior living is significantly far on the "incremental/transformative continuum," as discussed above. And then there is the Kinder Institute, which addresses one of the most critical issues of our time. Its focus is the place of American democracy in a world with many challenges to the very idea of democracy (e.g., religion, economic success, and

global positioning)—all raising questions about the somewhat naïve American idea that its democratic history “should be” a model for the rest of the world.

In all of these cases, infrastructure has been a key element of their success/promise. The many relevant infrastructure elements include physical facilities in all cases, leadership, faculty and other key personnel elements, fundraising resources, campus culture (e.g., interdisciplinary collaboration), political positioning, networking across higher education and beyond, and much more. On the one hand, these very significant initiatives would not have come to where they are without significant infrastructure (physical, personnel, etc.), and on the other hand, they would not have achieved the necessary infrastructure without VERY significant external resources or, in the one case, the strong institutional commitment to move forward with an opportunity to bring a transformative research program to the University (based, of course, on the presence of a unique and relevant resource—i.e., MURR).

References

1. American University. “Final Report: Task Force on High Impact Research.” May 26, 2015.
2. Economic and Social Research Council. “What is Impact?” www.esrc.ac.uk/research/evaluation-and-impact/what-is-impact/
3. Foster, Brian. “Promotion and Tenure Rituals: Where they have Taken Us, and Where We Are Going.” Vancouver, B.C.: Society for Applied Anthropology Annual Meeting, April, 2016.
4. Hossenfelder, Sabine. “What is transformative research and why do we need it?” backreaction.blogspot.com/2012/08/what-is-transformative-research-and-why.html
5. NSF. Introduction to Transformative Research. nsf.gov/about/transformative_research/definition.jsp
6. NSF. “Challenges of Identifying Potentially Transformative Research.” nsf.gov/about/transformative_research/challenges.jsp
7. NSF. Academic Research Infrastructure Program: Recovery and Reinvestment (ARI-R2). www.nsf.gov/od/oia/programs/ari/
8. NSF. “Definition of Transformative Research.” www.nsf.gov/about/transformative_research/definition.jsp
9. NSF. FAQs Regarding Academic Research Infrastructure-Recovery and Reinvestment (ARI-R2) Program Solicitation. NSF 009-562 – Part 1 www.nsf.gov/pubs/2009/nsf09051/nsf09051.jsp
10. UMBC. “UMBC50: Research Infrastructure.” Circa.umbc.edu/files/2013/10/Live-wire6-MicrokingdomCrop.jpg
11. Wikipedia. “Transformative Research.” en.wikipedia.org/wiki/Transformative_Research
12. Yasmeen, Gisele, “Social Science Infrastructure: North America (Research and Teaching). International Encyclopedia of the Social and Behavioral Sciences, 2nd edition, Volume 22. Elsevier, 2015. Pp. 593-603.