Future Knowledge Ecosystems

The Next Twenty Years of Technology-Led Economic Development

Anthony Townsend, Institute for the Future
Alex Soojung-Kim Pang, Institute for the Future
Rick Weddle, Research Triangle Foundation

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Abstract

The model of self-contained research parks and incubators that dominated the last fifty years of technology-based economic development is being challenged by deep shifts in the global economy, science and technology, and models of innovation. This paper describes fourteen emerging trends that will set the context for technology-based economic development in the coming decades. These trends are used to develop three scenarios for the future of technology-based economic development over the next two decades. In the first scenario, an incremental evolution of the research parks model takes place in a world of rapid, but steady and predictable change. In the second scenario, entirely new networks of R&D space emerge in a "research cloud" that challenges current models to adapt, sometimes dramatically. The third scenario, the research park models is in rapid decline as R&D becomes highly virtualized and parks' legacy cost structure makes them obsolete for young firms. We conclude by highlighting the strategic implications of these scenarios for existing and future parks and economic development.

FORECASTING WORKSHOP PARTICIPANTS

Forecasting and scenario development workshops were held during 2008-9. Organized by Research Triangle Foundation and facilitated by the Institute for the Future, these workshops were designed to engage a broad group of experts from different countries and different professions in brainstorming important trends and scenario elements. The results of these workshops are reflected throughout this report. The authors wish to thank Tina Valdecanas of the Research Triangle Foundation for organizing these workshops.

IASP 2008
Johannesburg, South Africa

Sue Bell
La Trobe University R&D Park

Joan Bellavista
Parc Cientific de Barcelona

Neville Comins
The Innovation Hub

Jeff Finkle
IEDC

Esteban Cassin
Fundacíon Parque Tecnológico
Misiones Argentina

Herbert Chen
Tsinghua University Science Park

Douwe Dijk
Zernike Science Park

Mauricio Guedes
Rio de Janeiro Technology Park

Dennis Kekas
NCSU Centennial Campus

Lex de Lange
Zernike Science Park

Malcolm Parry
The Surrey Research Park

Josep Miguel Piqué
22@Barcelona

Luis Sanz
Paulo C. De Miranda
IASP

Rick Weddle
Research Triangle Park

AURP 2008
St. Petersburg, Florida, USA

Pierre Belanger
Bellatech

Brian Darmody
University of Maryland

Bill Dean
Piedmont Triad Research Park

Greg Deason
Purdue Research Foundation

Charlie Dilks
Dilks Consulting

Vernon George
George, Henry, George Partners

Ron Kysiak
IDEA Partnerships

Amy Lubas
NCSU Centennial Campus

John Merrill
Gateway University Research Park

Ernest Paylor
WorldTech International

Fernando Quezada
Biotechnology Center of Excellence
Corporation

Liz Rooks
Research Triangle Park

Luis Sanz
IASP

Rick Weddle
Research Triangle Park

Bob Wilhelm
UNC Charlotte Research Institute

Bruce Wright
University of Arizona

IEDC 2009
Tempe, Arizona, USA

John Adams
Enterprise Florida

Dorothy Baunach
NorTech

Ronnie Bryant
Charlotte Regional Partnership

Gary Conley
TechSolve, Inc.

Gene DePrez
Creativesheffield

Michael Finney
Ann Arbor SPARK

Norma Grace
University of New Orleans

Jackie Kerby-Moore
Sandia Research Park

Paul Krutko
City of San Jose

Gail Lewis
AZ Department of Transportation

Judy McKinney-Cherry

Jay Moon
Mississippi Manufacturers
Association

Robin Roberts Krieger
Greater Oklahoma Chamber

Bill Sproull
Richardson Economic Development
Partnership

Eileen Walker
AURP

Steve Weathers
Regional Growth Partnership

Rick Weddle
Research Triangle Park

Online Expert Panel

To complement our face-to-face workshops, the Institute for the Future convened an online panel of experts in March 2009 to map trends in areas that will shape the future of technology-led economic development and research parks: real estate, architecture, economic geography, public policy, entrepreneurship, history of science, and incubation.

Thomas Campanella
University of North Carolina

Kamau Gachigi
University of Nairobi

Michael Joroff
MIT

Ilkka Kakko
Karostech Ltd.

Steve King
Emergent Research

Mitchell Moss
New York University

Fergus Murphy
SRI International

Margaret O'Mara
University of Washington

Hugh O'Neill
Appleseed, Inc.

Rachel Park
CUH2A

Matthew Zook
University of Kentucky

PART I. WHERE WE ARE TODAY

Introduction: A Postcard from 2030

Fast forward to 2030, and imagine a late afternoon in Soweto, once a stronghold of resistance to apartheid, now a hotbed of small technology firms bridging Western technology and African ingenuity and markets. Scattered across the community's 65 square kilometers, some 150 small factories and wet labs are engaged in short-run, small-batch manufacturing of lightweight infrastructure technologies of all kinds – solar-powered ovens, nanomesh water filtration, genetically modified seed lines specifically designed for micro-climates across the sub-Saharan region. Collaborative R&D is mostly done in community-funded pop-up labs, cheap facilities built out of shipping containers and governed by open patent agreements – whatever goes in or comes out of them is common property for the whole community.

For many, the future described here may be difficult to imagine, but it is a plausible one. It illustrates the degree of change that can happen in twenty years. In fact, the investment decisions we make today are likely to have impacts for at least this long.

Thus, ask yourself, would I recognize this as a research cluster? Would I call it a research park?[2] What does this possibility mean for how research parks are likely to evolve, in the developing and developed economies alike? In this world, what is the role of research park developers, managers and economic development officials?

The purpose of this white paper is, firstly, to explore the future economic, technological and geographical trends that might converge to make this vision a reality. Secondly, this is only one of many possible futures for technology-led economic development. Therefore, we present a set of three broad scenarios for the future of research parks and technology-led economic development.

Building on Success: A Brief History of Technology-Led Economic Development

2009 marks an important moment in the history of technology-led development. The Research Triangle Park of North Carolina turns fifty, and over 40 parks are twenty-five years old or more.[3] As we begin thinking about the next twenty years of change and innovation in this field, it makes sense to review how the movement has evolved and the source of its past successes.

The concept of the science city—a city built from the ground up to house scientific and technical research—emerged during World War II. The speed of technological development demanded by the war effort vastly exceeded any existing industrial R&D capability, and the concentration of existing research centers in cities was a security risk. As a result, both Allied and Axis powers created massive R&D facilities, isolated far from population centers. The British concentrated cryptography researchers in Bletchley Park; German rocket developers were centered at Peenemünde; and most spectacularly, America's Manhattan Project built remote complexes dedicated to atomic

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[2] Throughout this report, we use the terms *research park*, *science park* and *technology park* interchangeably. All refer to specific, contiguous development sites targeted to attracting and developing technology-intensive economic activity.

[3] 2009 survey of IASP members by Research Triangle Foundation.

bomb research and production in Tennessee, Washington and New Mexico.[4]

While the science city model was certainly effective at massive breakthroughs in both basic science and its technological applications, it was frighteningly expensive , and their geographic isolation meant that there were few opportunities for spin-off economic growth. The science city model was later used both successfully and unsuccessful in economies as different as Japan and the Soviet Union. Over time, the notion of science cities as a specific site gave way to "technopoles" as regional concentrations of public and private technological, financial and human capital.[5]

In the early 1950s, first at Stanford University and later in North Carolina, the science city model was adapted to a more manageable scale. Dubbed "industrial parks", "research parks" and "science parks" these projects were land-driven strategies primarily aimed at attracting the regional branch plants of large manufacturing companies. Over time, these places saw a growing share of their tenants engaging in research and development functions. In many countries such as Japan, France and the Netherlands, central governments played a major role in the creation of research parks. In the United States, research parks more often were the result of sub-national governments.[6] Over time, parks have tended to become more specialized, targeting specific industries or sectors.

By the 1980s, the strategic focus of technology-led development shifted from the attract-and-retain model of industrial parks to a model based on business incubation. While technology transfer was an element of the business model behind industrial parks, in incubators it moved to the forefront. The thinking was two-fold: dating companies was a zero-sum game playing regions off against each other, and growing firms locally would be more "sticky" and likely to produce secondary benefits. Beginning with the first known business incubator, established in Batavia, New York in 1959, thousands of incubators opened throughout the world. Today, some 3,000 business incubators exist worldwide, along with thousands of other facilities that perform similar functions under different monikers.[7] The incubator model also marked a shift away from lowering real estate costs as the primary strategy (though rents are still typically subsidized), to providing seed capital, management expertise and intellectual property management needed to grow small companies into big ones. Almost universally, incubators have been positioned around universities, in the hope of leveraging their research and talent.

Today, both the industrial park and business incubator model are widely used. However, in advanced industrial economies these models are less effective as the needs of startups evolve. In their 1991 study of U.S. research parks, Luger and Goldstein found that more than half of all research parks fail or shift their focus. Furthermore they found that "many research parks are unlikely to be appropriate for new start-up businesses, because minimum lots size requirements and high land prices make the cost of entry into

[4] "Science: Innovation in the City" *Ten Year Forecast: 2006*. (Institute for the Future: Palo Alto, California)
[5] Manuel Castells and Peter Hall, Technopoles of the World: The Making of 21st Century Industrial Complexes, NY: Routledge, 1994.
[6] M I Luger and H A Goldstein. 1991. *Technology in the Garden: Research Parks & Regional Economic DEvleopment*. (University of North Carolina Press: Chapel Hill, NC)

[7] National Business Incubator Association.

parks high."[8] Yet, existing parks still create great value for tenants, surrounding properties and regions – not because of the business model – but because they have become key nodes in larger knowledge ecosystems. This accrued value is being reflected in the market. For instance, land values at the Research Triangle Park have more than tripled in the last five years.

But, as we illustrate through one of our future scenarios, the next few years may very well be a period in which no significant new research park projects are launched, and some parks fail. Any number of factors could drive this scenario to the forefront – a protracted global recession, aggressive corporate cost-cutting and dematerialization of R&D or a return to high energy costs that put "legacy" parks at a carbon disadvantage. Signals of this future are already around us, from the endless delays of Russia's ambitious national technopark project to bubble-era university-based efforts like the Harry Reid Technology Park at the University of Nevada Las Vegas. Even current success stories such as Singapore's Biopolis have been called into question by the World Bank.[9]

On the other hand, the threat to existing parks could also come not from external economic shifts but from the emergence of entirely new models for building and organizing spaces for R&D. In our second scenario, "The Rise of Research Clouds" - digitally connected networks of small spaces challenge existing parks and by providing more collaborative, more flexible and less costly homes for invention. Again, signals of this future abound if we raise our heads and look at innovative communities outside our own circle of peers.

A third possibility, a very real future for many parks, is incrementalism - evolving and upgrading infrastructure and services to the next version, "Science and Technology Parks 3.0". Indeed, an upgrade is desperately needed. Cities and metropolitan regions are increasingly seen as the drivers of national economic growth, making it likely that we will see renewed interest in the research park model as an economic development tool. Yet, while this scenario may involve survival and a limited degree of prosperity for some, it does not realize the full potential for innovation and socioeconomic gains that future scientific breakthroughs may hold. It is a likely scenario for many parks in the absence of external threats, but not necessarily the most desirable one.

Towards Regional Knowledge Ecosystems

Despite their stark differences, in all of these scenarios, we find one common element – regions will play a more important role than at any time in the last century. In fact, there will almost certainly be regions in which all three of these scenarios play out simultaneously over the next twenty years, with upgraded research parks, research clouds, and vacant tracts of research parks that never were, all existing side-by-side. The simple fact is that the complexity of science and technology today is too big for any one campus, firm or research park to tackle in isolation.

The literature on knowledge ecosystems, developed in organizational studies over the last few years, provides robust framework upon which to develop a new understanding of how innovation happens in regions. A knowledge ecosystem refers to the events that occur as codified knowledge is

[8] Luger and Goldstein, p. 181.
[9] Yusuf S. 2006. *Postindustrial Asian Cities: Innovation for Growth*. (World Bank: Washington, DC)

transformed into tacit knowledge over time through learning and experience. Studies of knowledge ecosystems focus on how communities of practice interact with established bodies of knowledge and the tools and practices for upgrading that knowledge over time.

At least one study has explicitly applied the knowledge ecosystem framework to understand a technology region.[10] We believe that this framework can be used by the research parks and economic development community to better understand the processes by which communities of practice, embedded in metropolitan areas, generate "sticky know-how" that has real, unique economic value that is difficult to copy.

The regional knowledge ecosystem framework has several advantages. First, it focuses our attention not on the existing institutions of economic development - universities, research parks, large companies, venture funds, etc – but on the dynamics of how they interact with each other and new non-institutional elements (talent, bodies of knowledge, virtual communities). While the economic development field is awash in talk of "networks", the concept has lost all meaning. A rigorous application of knowledge ecosystem theory will allow us to begin specifying the kinds of networks and how they ought to operate. Second, it brings a holistic approach to how we think of innovation in regions – not as an isolated activity that happens within specific firms or clusters, but as a cohesive system. Dysfunctional knowledge ecologies are costly to organizations, but in a regional context, they also impose costs on everyone else (if only opportunity costs). Finally, the knowledge ecosystems approach is particularly attuned to understanding how organizations perform in "hyper-turbulent" chaotic environments, which certainly describes the global technological and economic landscape.

Applying a knowledge ecosystem frame to regions immediately yields several insights that may dictate strategic shifts in the way we approach technology-based economic development. First, while land and leased space will continue to underpin the economics of creating research spaces of all kinds, the real added value will increasingly come not just from providing services (as many parks already do), but from actively managing activities and knowledge creation. Second, as scientific knowledge and tools become available anywhere on-demand, focusing on global domination of any particular industry will lose effectiveness. Growing the regional ecosystem elements that provide the capacity for repeatedly re-inventing the cluster will become paramount. Third, all of these dictate a reduced emphasis on real estate development and infrastructure, and more emphasis on creating mechanisms that link local assets to global markets in ways that generate value.

Our understanding of this tool is in its earliest stages, and will require further development. However, our forecasting and scenario-building exercise points towards a crucial need in every technology region, for new governance structures that are broader than a single industry. Acting as a custodian of the regional ecosystem frame, this body could perform several functions. In the short term, new tools are needed for measuring and mapping networks and flows of knowledge, money and ideas. In the medium term, new business models for managing regional assets and creating something that is great than the sum of its parts. In the long-

[10] Bahrami, Homa; Evans, Stuart. 2005. *Super-flexibility for Knowledge Enterprises*. Ch. 3.

term, the challenge will be leveraging this ecosystem and its many networks to help firms and clusters compete globally - by collectively figuring out where a region fits into global R&D “supply chain”. Their goals will be to encourage knowledge creation at the cutting edge and develop the organizational, human and social capital to compete in the global economy. It would build networks that would stretch far beyond the major regional institutions of today to include informal networks of entrepreneurs, investors, professionals and hackers and other communities of mentoring and learning.

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This is where the Institute for the Future and the Research Triangle Foundation find ourselves at the end of this study. This is merely a beginning, however. We will continue to examine the findings of this forecast with our partners and the global network of science parks and technology regions.

We also will be working to develop realistic and implementable execution strategies that respond to the challenges of this forecast. These strategies will be shared in a “field manual” for existing research park and technology-oriented economic development managers – but also a framework for those considering the development of new parks or innovation-focused development programs.

We believe the only way to invent the future will be through systematic futures thinking, risk-taking and experimentation. If the research parks and economic development community does not do it, they will leave it to others to lead.

PART II.
TRENDS SHAPING THE FUTURE OF TECHNOLOGY-LED DEVELOPMENT

Our forecast research identified fourteen trends that will broadly set the context for technology regions and research parks over the next 5-20 years. They summarize keys global shifts in three domains: economy and society, science and technology, and the models and places for R&D.

Each trend identifies a direction of change and consists of four main elements:

Headline - a title that describes the overall direction of change

Description – what is happening in this trend? What are the key drivers and enablers?

Signals – what early indications of this trend are visible in the world today?

Impacts – how will this trend shape the context for research parks and technology-based economic development?

ECONOMY & SOCIETY

The first set of trends examines major global social and economic forces that will set the context for enterprises of every kind.

First, the current global economic crisis will echo for a decade or more, putting governments at the forefront of funding basic science and technology research and constraining big new development projects. Second, new technologies of cooperation will elevate the economic importance of small groups in elation to corporations and individual consumers. This will transform entire industries and reshape the need for collaborative space. Third, as governments and industries work to address global warming through carbon markets and taxes, the measurement of the economic value of ecological processes will be increasingly important.

From Free Markets to Stimulus Capitalism

The economic crisis of 2009 will turn the tables on markets, putting governments at the helm of the global economy for many years to come. Public investments in basic science and research infrastructure will be used as a primary tool to stimulate both short-term and long-term growth. In the United States, this shift is well underway, and in rising science powers such as the Gulf states and China, recent large public investments in research capacity will at least be are sustained and potentially will expand.

Signals

Harvard University will house Stem Cell Institute in renovated building instead of new science campus [http://tr.im/l8Wx]

2009 US economic stimulus provides $100b for science and technology [http://tr.im/l8Vx]

Corporate R&D spending holding steady, but real risk of decline in 2009 [http://tr.im/ilMz • http://tr.im/ilMH • http://tr.im/ilMQ]

China and Gulf States continue state-led development of R&D capacity and science cities [http://tr.im/lZOh • http://tr.im/mqC1]

Impacts

The economic crisis, and governments' massive response through new science funding, will have both short-term and long-term impacts.

An "innovation bottleneck" will form over the next 3-5 years, as companies trim R&D spending and focus on short-term, quick-to-market innovation during the crisis, and before the results of government-funded research projects can be commercialized. While companies will expand engagement with universities to accelerate technology transfer, there are few short-term solutions.

The supply of venture capital will be constrained, as new funds and less experienced angels who entered the industry in recent years retrench to safer wealth preservation strategies.[11] In global regions where venture capital markets are lacking or under-developed, the economic situation will slow the development of new funds and investor networks.

The real estate industry will continue to struggle financing new projects and will avoid taking big risks. Real-estate investment trusts that focus on research parks and lab space have been especially hard hit. Even universities acting as developers are not immune to the slowdown, as endowments have suffered in proportion to overall market declines of 30 percent or more. Public universities will face large reductions in government aid, severely limiting their ability to develop new labs and research parks.

Research clusters in developing economies are likely to make significant gains in market share for global R&D spending as they provide lower-cost alternatives to cost-cutting companies.

Finally, existing research parks are likely to see increased tenant demands for flexible lease arrangements, as they plan for greater resilience to future economic shocks.

[11] National Venture Capital Assocation and PricewaterhouseCoopers. *MoneyTree Report* [https://www.pwcmoneytree.com]

The Group Economy

New tools for cooperation will drive down the cost of forming groups around any shared interest, identity or activity. New models for creating wealth will emerge at the intersection of the social web and grassroots movements. Existing organizations will be transformed through the adoption of these tools and processes, becoming less hierarchical, more agile and more collaborative.

Signals

Companies adopt of social software as a knowledge management tool – Lotus Connections [http://tr.im/l972]

Meetup.com's rapid growth as a platform for organized ad hoc interest groups for face-to-face meetings [http://www.meetup.com]

Obama campaign financed largely by small donations made online [http://tr.im/l97d]

Science bloggers convention at Research Triangle Park [http://tr.im/l989]

Academic studies mapping scientific collaborations [http://tr.im/l998]

Impacts

As it spurs the creation of new kinds of ad hoc organizations, and transforms existing ones, the group economy will have major impacts for the kinds of places and spaces that are needed for collaborative innovation.

New kinds of organizations will seek "landing spots" for meetings of various kinds – scheduled daily, weekly or monthly meetups, and ad hoc gatherings around interests, ideas and current events. The space and infrastructure demands for these kinds of activities are dramatically different from those supplied traditional research park – less permanently occupied, private spaces and more think-tank type collaborative spaces. The need for temporary, flexible and even mobile spaces will grow dramatically.

The group economy will change the needs of existing organizations' space as well. Existing tenants will require more meeting and collaboration spaces, and less space for "warehoused" workers. The goal will be to put collaborative activities in spaces that can amplify group economies, and provide opportunities for discovery. As open innovation strategies spread, there will be greater need for co-locating company employees and outsiders within shared spaces.

Finally, the group economy will place new demands on the measurement techniques traditionally applied in economic development and research management. Today, most econometric data looks at outputs and uses existing organizations as its units of analysis – the firm, the research park, the region. However, in the group economy, there is are new needs to measure both the flows between organizations – the "in-between stuff" – as well as the dynamics of small groups forming outside institutional boundaries. How do we measure the substantial impact of organizations without organizations?[12]

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[12] C Shirky. 2008. *Here Comes Everybody: The Power of Organizing Without Organizations*. (Pengiun Press: New York)

Ecological Economics Comes of Age

As governments and industries work to address global warming by developing environmental trading markets, carbon taxes, and other mechanisms, the measurement of the economic value of ecological processes will be increasingly important.

The first major efforts in this area are around carbon. Today, carbon trading is based on estimation more than on the measurement of real systems. Evolving carbon markets from estimation to measurement will generate complex scientific and technical problems requiring transdisciplinary solutions. Figuring out precisely how much carbon is sequestered in a particular preserve in Indonesia or Brazil, and how to turn that scientific knowledge into financial instruments will require basic research in botany, ecology, climate science, geology, remote sensing, and even accounting. As a scientific endeavor and information service industry, this will draw upon technological advances in sensing and measurement, simulation and supercomputing.

Signals

Carbon trading markets are growing rapidly, estimated to trade hundreds of billions of dollars of credits worldwide. [http://tr.im/lZOB]

Efforts to construct valuation of environmental services (beyond environmental impact studies) [http://www.iftf.org/node/2789]

Growth of bilateral trading regimes (e.g. between Northern companies and Southern forest preserves), supporting specific investments or environmental initiatives. [http://tr.im/mqEt]

Commercialization of carbon offsets and their widespread adoption by travel agents and travel sites.

Growing availability of personal carbon tracking estimators for travelers. [http://tr.im/lM3l]

Impacts

The next decade will see the introduction of a new generation of sustainability-related practices, technologies and services, built less around estimations of the environmental impact of manufacturing, transportation, and resource/energy use, and more on the measurement of actual resource use and pollution.

In this new industry research parks can serve as test-beds for innovative environmental management practices and services. For companies developing these services, fellow research organizations are likely to be valuable beta-testers and early adopters. Research parks located near economically valuable and productive ecosystems could be attractive locations for both researchers developing tools for measuring ecological activity, and entrepreneurs developing instruments for monetizing that activity.

Developing countries seeking to leverage natural resources could turn carbon offsets into a mechanism for technology transfer. By linking investment in science and technology infrastructure to carbon mitigation instruments, they could boost their own capacity for ecoscience at the same time they provide a valuable ecological service to carbon-hungry developed economies.

SCIENCE & TECHNOLOGY

Evolving in parallel to trends that will transform the economy and society over the coming decades, the subjects, methods, talent and institutions of scientific research and technological innovation will shift as well.

Five trends will have the greatest impact on technology-based economic development and research parks:

Biology by design will supplant physics as the most scientifically vibrant and economically important field, letting us read and write nature's "source code" at will.

The spread of **ubiquitous computing** will create massive new streams of research data, while simultaneously providing new tools for scientific collaboration in the lab.

Social networks where people and computers work together to make sense of data will enable a shift **from artificial intelligence to hybrid sensemaking**.

New scientists will transform the practice of science by forging transdisciplinary fields, multi-sector careers and bringing new cultural influences to bear.

Science institutions will be transformed as collaborative, open and online models for collaboration and knowledge sharing break through obsolete barriers.

Biology By Design: Nature as Source and Code

From synthetic genomics (which seeks to design micro-organisms that perform useful functions) to stem cell therapy (which seeks to harness the body's own ability to heal itself), biology will become a central source of scientific and technological breakthroughs. Key drivers include global ecological challenges, the health needs of a richer, aging global population and advances in informatics that help decipher the code of life. Biological concepts about how to organize systems and structures will also inspire designs for everything from buildings to organizations to algorithms. Yet many experts believe the biotech industry is structurally unsound – without change it won't be able to fully realize the commercial potential of these new technologies.

Signals

First synthetic genome created by J. Craig Venter Institute [http://tr.im/lfHL]

Scripps Florida biomedical research center opens in Jupiter, Florida, home of the largest chronically diseased population in the world [http://www.scripps.edu/florida/]

Massive public investment in biotech at the sub-national level [http://tr.im/lfMW]

Transdisciplinary and translational biomedical research centers at Stanford, MIT and UCSF

Google launches venture fund, which will make some investments in biotech "to keep an eye out for disruptive ideas to its core search business that might come from unexpected fields, such as biotech." [http://tr.im/lZDi]

Impacts

Biotechnology has not lived up to its economic promises – as Harvard professor Gary Pisano notes, while biotech has attracted more than $300b in capital over the last 30 years, it has produced profitless growth. Synthetic biology may change that, and increase the demand for research space over the coming decades. So-called "white" biotechnology – industrial biotech for producing fuel and materials may just be mundane and scalable enough to produce sustainable profits, unlike earlier generations of "red" (biomedical) and "green" (agricultural) biotechnology.

In the meantime, however, the sector will continue to require massive public investment in basic science to jumpstart economic activity. In the United States, state governments have invested heavily ($500m for California's Institute for Regenerative Medicine, $1b for the Massachusetts Life Sciences Initiative, and $1.2b in North Carolina over the last decade). None of this will change the fundamental structural issues in the industry, which is largely borrowed from Silicon Valley's information technology (IT) industry, and which Pisano argues are stifling innovation. Larger efforts, involving public, private and NGO stakeholders will have to address these on a broader scope.

Biotech will also diverge from the IT industry in the ways and places in which it clusters. First, the translational nature of biomedicine means that researchers are often moving from lab to bedside frequently, requiring them to be located near research hospitals in large population centers, often in the center of large cities (versus a suburban research park). Second, it often involves specimens that cannot be removed from the lab – distributed work is less important since much of the "code" is not portable as in the software world. Third, while IT infrastructure is becoming highly distributed, many of the most advanced biomedical research tools are becoming highly centralized. For instance, the next generation of high resolution MRIs used in brain imaging research weigh dozens of tons and take up an entire building.[13] Finally, biological research will always entail a certain level of public health risk – while many factors cited above point towards centralization, the need to isolate hazardous materials may push in the other direction – some bioresearch will need to be located far from population centers.

The sheer complexity of bioscience will require radically new approaches to designing research organizations. Research at the intersection of biology and informatics, and biology and nanotechnology, for instance, requires bringing together different disciplinary skillsets in the same place or even the same person. Parks and regions that can tap multiple disciplinary centers of excellence, or partner with transdisciplinary organizations and research communities will be well-positioned for biomedical innovation.

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[13] Siemens AG. Fall 2008. "Magnetic Mission" *Pictures of the Future*. p.88.

Ubiquitous Computing

The spread of ubiquitous computing (ubicomp) - the diffusion of unobtrusive digital sensing, computation and communications technologies into ever-larger parts of man-made and natural environments - will create vast new datasets for scientific research in fields from public health to civil engineering to marine biology. Mobilizing this computational infrastructures will require intensive collaborations between IT specialists, scientists, and engineers. But once in place, ubiquitous computing technologies will also generate very large quantities of information from everyday activities like travel, shopping, and communications. This will have substantial commercial value to companies that can manage and analyze it quickly enough. More importantly, it will enable new research in social science, public health, and field sciences that will contribute to the further quantification of these fields.

Signals

The growth of environmental sensing research in ubiquitous computing, such as the Living Environments Lab at Carnegie-Mellon [http://www.living-environments.net/]

Research in "smart dust," cubic millimeter-scale computers that within a few years will allow us to place computing and reactive capabilities in a wide variety of built objects and environments [http://tr.im/mqIz]

The growth of low-cost displays, and their diffusion into a variety of use contexts and devices, ranging from cellphones and iPhones to wall-sized digital billboards.

Impacts

Ubiquitous computing will collapse many of the distinctions we take for granted when doing everything from designing scientific research projects to designing research spaces. The distinction between online and offline environments, digital and physical worlds, even between natural and artificial, break down. This does not mean that physical places will become irrelevant: instead, the smart deployment of well-designed digital resources, and the early adoption of new digital technologies, will set smart places ahead of the pack.

On the research front, ubiquitous computing creates opportunities and demands for new forms of cross-disciplinary research. Because ubicomp creates the potential to blend digital resources with a wide variety of materials and environments, research parks could create value by bringing computer scientists and engineers together with sculptors, textile designers, architects, and anthropologists-- or with craftsmen and workers from established, mature local industries. It will also create a need for hyper-wired, digitally-mapped, configurable spaces that can be used as test-beds for new technologies.

Ubicomp will also create a need for "living labs" like Seoul Digital Media City or Singapore's Fusionpolis that combine vibrant real-world communities with research and prototyping. Ubicomp is as much about the use of technologies as their deployment; having spaces in which users can realistically interact with prototypes or enhanced spaces can generate valuable experiences and insights for researchers, retailers, and designers.

From Artificial Intelligence to Hybrid Sensemaking

For decades, computer science sought to create artificial systems capable of duplicating and even replacing human reasoning and communications. In the last few years, the excitement around collective intelligence experiments on the Web has established the value of a different approach: the creation of hybrid structures that combine social networks and more limited forms of machine intelligence, to collaboratively filter and extract meaning from data about our environments and ourselves. Such systems allow computers and humans to each do what they're good at, and mix together formal and tacit and social knowledge. More broadly, the growth of these tools reflects a more nuanced view of intelligence as an inherently social and contextual thing, not something reducible to computer cycles or logical statements.

Signals

MIT and NYU trials of workplace infrastructures that mine social interaction data [http://tr.im/lM8Z]

Experiments with "artificial artificial intelligence", like Google's Image Search Game and Mechanical Turk, platforms for small tasks are trivial for humans but extremely difficult for computers.

A San Francisco-based startup seeks make scientific distributed computing (made famous by SETI@Home) more accessible by combining a simple computing infrastructure with social networking tools to reach small, rich pools of talent or expertise.

The Network Oasis in Joensuu, Finland's GLOW system helps managers of an incubator space "manage serendipity" by understanding who is present and their skills and interests [http://www.globaloasis.fi/glow/]

Impacts

Artificial intelligence sought to make humans obsolete – as a corollary, it would have made place less relevant. But hybrid intelligence relies on a mix of unique places, strong algorithms, and vibrant human networks. Hybrid intelligences require interesting or unique working spaces, workplaces or other infrastructures that facilitate nonverbal communication.

Not only are there opportunities for research parks to provide rich physical spaces supporting hybrid intelligences. Hybrid intelligence could become a distinguishing feature of highly effective collaborative research spaces. By providing infrastructure and "reality mining" services, parks could distinguish themselves and move up the value chain.

Hybrid intelligences often mobilize around very large, uncertain bodies of information. These are too complex and specialized to be usefully analyzed using commercial-grade Internet connections and servers; the grid computing architecture developed for high-energy physics is likely to be replicated in other fields. Research parks that can provide very fast access to grid-scale computational resources, often in support of groups of scientists or social networks, will have an advantage over less-connected competitors.

The growing popularity of publications like the Journal of Visualized Experiments (JoVE) suggest that a new generation of experimental scientists will see the value of systems that allow them to communicate tacit knowledge at a distance. By employing hybrid approaches to map what people are actually doing in research environments, labs can help codify some of the things that were previously craft and technique.

The New Scientists

The next generation of scientists will transform scientific practice, the way scientific careers are constructed and managed, and the sources of knowledge they draw upon and develop in their work. As options outside academia grow, publishing becomes more open, collaborative and real-time, and entrepreneurship gains more legitimacy, the means by which scientists create professional reputation will be transformed. These new scientists will be both transdisciplinary and ultra-specialized, drawing on various disciplines to answer complex, focused questions. The role of amateurs will expand, as both independent researchers and partners of professional science. Scientists from emerging economies will introduce non-Western cultural, ethical and intellectual traditions into the practice of modern science. Science will also provide a path for women to achieve gender equality in nations with a high degree of gender segregation.

Signals

Increased competition for academic jobs, as PhD production increases and tenured faculty stay on staff is driving many doctoral graduates into private sector jobs. [http://tr.im/m20o]

The Princeton Review and Fortune Small Business now produce annual ratings of the best schools for entrepreneurs - institutions are beginning to see these students as a significant segment of their market.

Reward for entrepreneurship in tenure review is encouraging more young scientists to develop academic-industrial "bricolage" careers, moving back and forth between universities and business.

Universities are responding to student desires for more transdisciplinary education especially around design: Finland's Aalto University (created through the merger of 3 pre-existing universities), Stanford's D.School, and Design London (a joint program of Imperial College and the Royal College of Arts) [http://tr.im/lmvl]

"Scientists of the self" are using ubicomp technologies to monitor their own bodies and lives, generating volumes of data and unorthodox research questions. [http://www.quantifiedself.com/]

Science is actively engaging many more amateurs, who may go on to science careers or make significant contributions to formal research projects (SETI@Home, Birdsource).

Impacts

New scientists will have dramatically different expectations about career mobility and the ability to pursue independent intellectual interests outside of employment contracts. They will have greater demand for continuing education and learning experiences, and will want work environments where they can maintain connections to their social networks and outside sources of knowledge.

The role of social networks will be extended in other ways that impact econmic development. One of the most important assets being cultivated by large companies are their corporate alumni networks. As research parks and technology regions are increasingly selling community as a highly valuable aspect of location, creating membership-type organizations for "park alumni" might make sense.

Research parks and regions have long marketed themselves as attractive places for companies. As Richard Florida argues, places now need to be attractive to workers as well, if not primarily.[14] However, in between these two layers, parks also need to think about how they appeal to small groups of new scientists – the clubs, mailing lists, and other rich networks that really connect and define innovative communities.

Finally, many of the new scientists will not be professionals, but amateurs. Parks have historically done a terrible job connecting to educational institutions and youth, if they have bothered at all. Connecting to amateurs will entail some of the same challenges, but also reap potentially larger rewards. As volunteer champions of science, amateurs represent a vastly under-utilized resource for parks and their tenants. And the failure to engage them in real world R&D is a lost opportunity to upgrade the region's human capital through experiential learning and training.

[14] R Florida. 2002. "The Rise of the Creative Class: And How It's Transforming Work, Leisure, Community and Everyday Life" (Basic Books: New York)

Science Institutions Transformed

Experiments with new organizational forms, incentive structures, and rewards will shake the foundations of centuries-old scientific institutions. Scientific publishing is already under full-scale attack, its economics and social conventions completely undermined by cheaper, faster, or more democratic online alternatives and by entirely new forms of publishing like video. Privately funded research centers like the Perimeter Institute, Kavli Institutes, and Jenalia Farms are experimenting new ways of funding and organizing research, and measuring the output of scientists. Scientific challenges like the X Prizes are coalescing into a parallel and competing incentive structure for innovation. Finally, the sheer complexity of the scientific challenges of the 21st century will require massive new global partnerships that cross political and organizational boundaries.

Signals

Prizes and challenges are emerging as a substantial incentive for innovation in sustainability and other global problems. [http://www.signtific.org/en/signals/technology-prizes-and-challenges-innovations-sustainability-and-global-problems, http://www.signtific.org/en/signals/using-prizes-not-patents-support-drug-development-developing-world)

Hedge funds are partnering with academic mathematicians and physicists to develop new tools of interest to financial engineering and science; others are supporting research in high-energy physics. (http://www.signtific.org/en/signals/hedge-fund-university-partnerships ; http://www.signtific.org/en/signals/hedge-funds-new-cool-places-basic-science ; http://www.signtific.org/en/signals/private-funding-high-energy-physics)

A wide range of institutions and entrepreneurs are developing alternatives to traditional scientific publishing, which has helped shape professional practices and rewards for decades.

Impacts

The growth of new kinds of scientific institutions may create new clients for research parks: private equity-funded laboratories, institutes created to solve specific high-profile problems. However, while some will be working at a scale and pace similar to companies and academic institutions, others may not, and may be designed to operate for only a few months or a year.

Research parks need to be sites in which virtual networks can coalesce into meetups, conferences, etc. They also need to be places that can support virtual work and new forms of publication. Research parks might also attract new institutions by developing their own science or technology prizes, or partnering with organizations offering prizes.

In some parks and regions, critical science institutions may need new sources of external support, or risk failing entirely. The crisis facing the newspaper industry today may be a particularly illustrative one. Once unthinkable, the failure of a crucial institution that could have massive impacts on local politics and economies, is now a reality in every city. Should parks and institutions struggle to save dying institutions, or help fledgling alternatives grow stronger to take their place?

MODELS & PLACES FOR RESEARCH & DEVELOPMENT

The final set of trends looks at how organizational structures and business models for research and development are changing, and emerging ideas about how to configure these activities at various scales – the lab, the building, the campus, the region and the globe.

Six trends are shaping the future of R&D:

A new **global map of science** is emerging, in which smaller countries are playing an increasingly important role, challenging the Western superpowers' centuries-long dominance.

New models of **lightweight innovation** seek to do more, faster with less, and cast a broader net for ideas.

Universities will continue their transformation **from ivory tower to economic engine** and play a greatly expanded role in economic development – in time, it could become their primary function, trumping education.

Economic development practice will shift from trying to copy the success of others to building **sticky know-how** – tacit knowledge that builds on local cultural and industrial resources, and isn't mobile.

Greater attention to the **social life of small research spaces** will create dynamic, transdisciplinary places that bring virtual networks to ground.

Regional knowledge ecosystems will emerge as a new strategic frame, providing scale, efficiency and global platforms for economic development.

New Global Map of Science

If science in the 20th century was a pyramid, with the United States, the United Kingdom, Germany, Russia, and Japan at the apex, science in the 21st century will be more like a network, with multiple, linked centers of excellence. Successful countries and sub-national regions will pursue strategies to blend targeted investments in basic science with local industrial or cultural resources, to create unique and hard-to-reproduce centers of excellence. These centers will be designed to capture critical niches in complex global R&D "supply chains". Meanwhile, the shift from brain drain to brain circulation; the rising capability of moderate Islamic states to support scientific communities; and the growth of new "South-South" collaborative networks mean that these centers of global excellence can develop in a wider range of countries than in the 20th century.

Signals

Growth of South-South research cooperation [http://tr.im/la34]

Chinese universities hiring top global talent [http://tr.im/la6S]

R&D partnership between The Hamner Institutes for Health Sciences and China Medical City [http://tr.im/lLZd]

Fewer doctoral students staying in the US after graduation [http://tr.im/la6q]

Globally mobile universities – NYU in Abu Dhabi, JHU in Nanjing, Georgetown in Qatar

"Bamboo ceiling" for Asians in U.S. firms[15]

Impacts

New research clusters in developing countries will capture an increasing share of global R&D investment, and increase the volume and value-added in technology innovations. Some of this will certainly come at the expense of existing industries in developed economies, through offshoring of "routine" R&D functions.

Globally networked science will necessitate a shift from zero-sum competition and efforts to replicate Silicon Valley's broad knowledge ecosystem, in favor of highly focused efforts to develop niches in global technology supply chains. This strategic shift will be pioneered by new clusters in emerging economies, seeking to be globally competitive at the cutting edge in narrow areas of opportunity.

Global science also means greater mobility of talent. As wage differentials shrink, returning home will be more attractive to foreign students – developed countries will need to offer additional value, such as a better business environment or easier access to startup funding. U.S. universities are responding by exporting their "brands" to developed and less-developed countries. We will also see scientists with global mobility that is more complex than simply moving between two countries – they may migrate multiple times to emerging centers of excellence.

Finally, global science will create more demand for "soft landing" zones for foreign companies expanding into new markets and joint ventures, which could provide an additional source of science park tenants, as "soft landing" companies outgrow their incubator space. Innovative regions will need to provide a broad variety of these spaces and market them through existing business networks.

[15] J Tang. 1997. "The Model Minority Thesis Revisited: (Counter)Evidence from the Science and Engineering Fields"*The Journal of Applied Behavioral Science*, Vol. 33, No. 3, 291-315

Lightweight Innovation

Over the next decade, new economic realities will increase the pressure to innovate faster and cheaper. New ideas about how to organize the innovation process, combined with dramatically cheaper tools for invention that put advanced research technology in the hands of small firms, will enable new lightweight models for commercializing knowledge. More and more of new product and service development will happen outside of existing pipelines. Lightweight innovation will reinforce the strategic shift of innovation activities out of large firms into broadly defined "open innovation" networks.

Signals

Innovations in early-stage investment: BetaWorks,Y! Combinator and AngelSoft

Falling costs of tools of invention – cloud computing, 3-d prototyping and desktop genomics

Crowd-sourcing innovation: Kluster [http://www.kluster.com]

Innovation clubs and Fab Labs in Kenya [http://www.fablab.co.ke/]

Impacts

Lightweight innovation points towards a growing role for startups in innovation systems at every scale – local, regional, national and by industry. Yet few research parks and economic development agencies are well-equipped to assess and address the needs of startups.

The most important shortcoming is in the area of startup financing. A growing array of smaller startups will seriously challenge traditional venture investing models, which simply cannot produce a profit on small deals. In some areas like biotech, this early-stage funding gap is being filled by corporate strategic venture funds. There will be an increased need for deep local networks of angel investors and small-scale seed funds – but these need to be run by seasoned entrepreneurs. "Dumb money" from investors without expertise or connections, has far less value than "smart money" that does.

The growth of startups, especially very small ones will create a "long tail" market for R&D Space. Instead of a handful of anchor tenants, a long tail is a large collection of very small firms that add up to significant demand. Since existing parks are mostly designed long-term leasing to large companies, a mismatch may emerge.

Incubation of lightweight startups will be a fundamentally new proposition. Just a few years ago, it took millions of dollars of venture capital, dozens of programmers, and a year or more to bring a new software product to market. Today, agile web startups move from idea to implementation without traditional incubation.

Access to "heavy" R&D tools will never disappear completely, except in a very few areas of technology. Research parks can play an important role in aggregating demand and subsidizing costly equipment. Especially in the developing world, where access to equipment is often the greatest obstacle to innovation for micro-financed inventors, this will be critical.

New innovation models are driving new approaches to intellectual property management, which will require managers of research spaces and communities to rethink how they support companies. The traditional focus on helping companies protect their IP, may need to shift to helping them open their IP to potential partners or new communities of innovation.

Universities: From Ivory Tower to Economic Engine

Several interacting forces will expand the modernization of universities' role in the economy. First, increased public investment in basic research will raise public expectations about the social and economic impacts produced by universities. Second, companies will continue to outsource research to university partners, amplifying the need for efficient technology transfer. Third, global competition between universities will foster more entrepreneurial initiatives to secure talent and find new sources of financial support. Finally, developing countries will rely heavily upon universities to jump-start new technology-based clusters.

There is a great degree of uncertainty about this shift. There is still considerable debate about whether "universities should deliberately do more to encourage the development of products or companies."[16] And while the .Edu Impact portal (http://www.edu-impact.com/) has cataloged over 90 economic impact studies of universities in the US and worldwide, this is largely a defensive exercise by universities seeking to avoid taxation by local authorities, not a demonstration of university vision or public policy.

Signals

Texas - state officials requested that the words "technology commercialization" and "economic development" be added to university and college mission statements.

UK 2015 Research Assessment Exercise will "for the first time examine factors like citation rates and the economic impacts of the research in question."[17]

The number of people employed in the technology transfer offices of U.S. universities more than doubled between 1998 and 2007. [signtific URL TBD]

Harvard University's Technology Accelerator Fund – $1.5m in annual grants for faculty to refine research to attract private capital.

Growth of university-based angel networks in the United States, Canada and Spain

New technology transfer mechanisms like the Alfred E. Mann Institutes, "proof of concept centers" [http://tr.im/lZPB]

Innovation zones, like the Greater Oakland Keystone Innovation Zone, a partnership of Carnegie-Mellon, the University of Pittsburgh, the state of Pennsylvania and several non-profit organizations.

Impacts

The most aggressive universities will completely transform their promotion systems, deeply integrating incentives for entrepreneurship. Some universities (such as the University of Iowa and Texas A&M) now identify patents, patent applications and involvement in tech transfer as evidence in tenure review. Some universities are even willing to reward faculty who have proven their effectiveness in economic development as highly as academic stars.[18]

As the share and volume of basic research done at universities rises, technology transfer will either exceed or fail to meet

[16] *The Future of the Research University: Meeting the Global Challenges of the 21st Century*. 2009. (Ewing Marion Kauffman Foundation: Kansas City, MO)

[17] "Peer pressure" *SEED*, April 2009, p 20

[18] For example, Alain Kaloyeros, who attracted more than $2.4 billion in federal, state and corporate funding to make the University at Albany a center of nanotechnology and semiconductor research, was paid a salary of $696,000 in 2008.

public and corporate expectations. Flaws in prevailing models for managing technology transfer will become more apparent, such as the preference for patents that produce short-term profits over more challenging long-term commercialization projects. The backlog of research generated by stimulus funding may skew incentives even further in the wrong direction, and leave many promising technologies languishing in the lab.

On the other hand, greater competition between universities will encourage more experimentation by universities in technology transfer and IP management. More universities will develop strategies and resources for supporting other means of promoting commercialization and entrepreneurship than only patent licensing.[19] Others will create internal competition - putting outside agents on equal footing to compete with their own technology licensing office. Still others will partner to create multi-university offices that can achieve a more efficient and effective scale.

The role of research parks, incubators and other facilities for technology transfer will change rapidly. As expectations for technology transfer grow, universities will diversify their strategies for spin-off spaces. This will mean shifting from a single research park model to investing in entire "innovation zones". In this model, rather than merely developing an urban research campus, universities act as long-term participants in the ongoing revitalization of urban neighborhoods or districts. These districts are mixed-use, combining both academic and commercial research activities with residential, office, retail, and cultural uses. The goal is to create an environment that helps attract, nurture and retain talent, and to encourage innovation across a wide range of other enterprises as well. Extending this strategy, more incubation spaces may be inserted directly into campuses and university buildings.

Entrepreneurial universities are not without their critics. Gary Pisano argues that aggressive commercialization of university bioscience research is actually limiting the industry's development by reducing the pool of shared scientific knowledge. His solution: "[t]hey should focus primarily on maximizing their contributions to the scientific community, not maximizing their licensing revenues and equity returns."[20] And there is a clear impact on the academic environment in entrepreneurial universities - when research parks are close by, the curriculum tends to shift from basic to applied research.[21]

Some universities will be unwilling or unable adopt a new model, and will produce limited economic benefits. We are also likely to see the emergence of new universities where economic development, not education, is the primary mission. Most will fall in the middle. As one study summarized the future: "In our view, universities… increasingly have no choice whether to be entrepreneurial, although like for-profit firms, they do have a choice about how they go about doing so."[22]

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[19] R E Litan, L Mitchell, and E J Reedy, "The University As Innovator: Bumps In The Road", Issues in Science and Technology, Summer 2007.

[20] Pisano G. 2006. "Can science be a business? Lessons from biotech" *Harvard Business Review*

[21] A N Link, J T Scott. "U.S. science parks: the diffusion of an innovation and its effects on the academic missions of universities" *International Journal of Industrial Organization*.

[22] (Kauffman p124)

From Knowledge Diffusion to Sticky Know-How

Advocates of innovation economies often see knowledge as both infinitely mobile and disconnected from its origins. Knowledge can be produced anywhere, this thinking goes, and high value-added, knowledge-intensive activities can be decoupled entirely from manufacturing. Both are wrong.

Many bench scientists can't take their work home, and some can't work outside one-of-a-kind facilities. Innovation often has a geographical or social "stickiness" to it because it can draw on combinations of scientific knowledge, technical skill and tacit knowledge that are place-specific. Nor is innovation so easily distinguished from manufacturing: many high-tech innovations have emerged while solving manufacturing problems, and contrary to popular perception, making things-- especially innovative new products-- is a highly complex, creative activity. Indeed, future industries, like the translational research paradigm emerging in the biomedical world, are likely to place a higher value on the tacit knowledge required to move new scientific discoveries from the laboratory to store shelves, doctors' offices, and living rooms.

Signals

Zaha Hadid's Central Building for BM's Leipzig plant deliberately seeks to mix white-collar and blue-collar workforce as a spur to innovation [http://tr.im/lZT5]

Rise of "guild" workspaces, such as Pixar in Emeryville, Calif. where large freelance contractor workforces are co-located with corporate customers during production.[23]

Venture capitalists are being recognized as tacit knowledge brokers who acquire and create intelligence about industries, market conditions, entrepreneurs and companies through a constant process of interaction and observation. This knowledge is then used to select promising industries, find good firms, and assist portfolio companies.[24]

Venture capitalists' are the center of a tacit knowledge exchange system that gives them lots of exclusive know-how. They are also able to speed this process to provide their portfolio companies an advantage.

Trade fairs are "temporary clusters" that provide mechanisms to share tacit knowledge exchange over long distances.[25]

Intel "Copy Exactly" in which Intel copies successful factories, right down to the paint colors, on the theory that they don't always know what makes a factory successful, so just copy everything. [http://tr.im/lZXh]

Impacts

Partnering or providing space for groups that have skills very different from conventional R&D, but can contribute to the development of innovative products or services-- arts or cultural groups, human factors or ethnographic researchers, even financial engineering firms-- may encourage unique cross-fertilizations that forms the basis of competitive advantage.

Some research parks will be able to maintain their viability if they can both attract interesting people, and co-locate near useful industries or important markets.

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[23] Myerson J. 2006. *Radical Office Design*. (Abbeville: New York)

[24] Zook M A. 2005. *The Geography of the Internet Industry: Venture Capital, Dot-coms and Local Knowledge*. (Blackwell: New York)

[25] Bathelt H and Schuldt N A. 2008. "Between Luminaires and Meat Grinders: International Trade Fairs as Temporary Clusters". *Regional Studies*. 42:853-868.

Boutique parks designed to bring together highly specialized clusters of existing tacit knowledge could incubate new technologies and innovations. For example, these could support creative work combining older industrial knowledge with new high-tech expertise.

For innovations in "brownfield" industries, critical challenges aren't just technological, but also regulatory, legal and financial. Research parks specializing in areas like cleantech, environmental remediation, alternative energy, and sustainable development would be smart to attract experts in finance, law, and technology policy.

Manufacturers who want to move up the value chain could be a target for new R&D parks.

The Social Life of Small Research Spaces[26]

Traditional business incubators will fade away, replaced by new kinds of spaces for entrepreneurship and collaborative research. Pop-up labs, co-working hubs, mobile incubators and disposable research parks will provide flexible physical spaces for R&D. Rather than warehousing workers, they will meet a need for communal collaborative meeting space in a world of increased mobility within and between workplaces. They will be neutral places where networks of investors, entrepreneurs, hackers and customers converge for collaborative knowledge creation and trust-building, cementing relationships initiated and cultivated online. Overlaid grids of social software will enhance serendipitous discovery inside these spaces and knit them together in local, regional and global networks of collaboration.

Signals

The rise of coworking and communal rent-a-desk and drop-in offices - http://tr.im/lkjQ

Kitchen Budapest, a "pop-up" media lab [http://www.kibu.hu/en]

Angel network in residence at Cambridge Innovation Center [http://tr.im/lkke]

Throw-away research parks – Phase Z.Ro in Singapore [http://tr.im/lkkt]

[26] The title of this section is a reference to Willam "Holly" White's pioneering videographic studies of how people use public spaces, conducted in New York City in the late 1970s, and presented in a film and book titled *The Social Life of Small Urban Spaces*. [http://www.pps.org/info/products/Books_Videos/social_life]

Oklahoma City's mobile biotech incubator – relocate the incubator instead of the growing company [http://tr.im/lklf]

The Hub's global network of social enterprise incubators [http://the-hub.net]

Charge-by-the-hour incubator space [http://www.globaloasis.fi/]

Impacts

The collaborative magic of small research places depends heavily upon the ability of managers to "produce" and "direct" the space like a "show" on a daily basis. This involves coordinating events, both formal and informal, ensuring a steady flow of new people and ideas through the space, and making connections between participants. This is a very different set of skills than the typical research park manager or economic developer today. The shift from managing land use and real estate to managing activity (or both) will require a fundamental shift in perspective.

Small research spaces are the physical side of lightweight innovation, allowing big companies and their smaller partners to come into direct contact. As architect Frank Duffy writes, "Conventional office developments exclude or marginalize workspace at lower rental levels and thus diminish the possibility of mutually beneficial interactions between large, mature businesses and smaller, growing enterprises." Simply moving small bits of the company out of the main campus (like Corning, Yahoo! and Intel have done in recent years) will not be enough. Corporations and startups will need to co-locate within the same buildings, forming "coalitions of interest".[27]

Small research spaces, because they lack the scale of research parks, are heavily dependent upon social networks to extend their reach and connect to external resources. Social networks are the demand generators for these spaces, as online communities develop needs for ad hoc, temporary or on-demand meetings, these spaces will need to develop business models to meet those needs.

The new leasing arrangements of small research spaces – monthly, weekly, daily, and even hourly rate structures - will overturn the supply chain for commercial real estate, which evolved around long-term leases of 10 years or more. As Duffy points out, conventional leases block feedback from users in the design and construction business. By providing direct daily feedback to property managers, research "hotels" might introduce end-user innovation to architecture for the first time in a century.

Many of these small spaces are driven by more than just business objectives. A growing number seek to further social goals by incubating social ventures (Front Seat Software in Seattle, The Hub in London) or by gathering disparate firms and communities in just-emerging sectors like sustainable design (Treehouse Brooklyn).

Finally, small research spaces present an opportunity to make R&D more transparent – engaging not only partners, customers and suppliers, but also a broader public as well. Already, we see many firms engaging lead users through beta tests and iterative design processes – it is only a matter of time before the physical organization of research adapts to support these activities.

[27] F Duffy. 2009. *Work and the City*. (Black Dog: London)

From Research Parks to Regional Knowledge Ecosystems

Translational research – science that transcends basic and applied research – and successful commercialization of the resulting technology, will grow increasingly complex. To succeed, these efforts will require coordinated investments at the regional level, because no single organization will have the capacity to perform all of many steps between lab and market. Because of this, we will see an expansion of new institutions and governance structures operating at the regional level whose goal will be to encourage knowledge creation at the cutting edge and develop the organizational, human and social capital at the scale needed to compete globally. These institutions will stretch far beyond the regional networks of today to include not just university and corporate leaders but also entrepreneurs, investors, professionals and amateurs. By their very nature, regional knowledge ecosystems will transcend traditional industry boundaries, seeking to create capacity to quickly re-invest resources and re-invent industries in response to global shifts.

Signals

East Bay Green Corridor in California – coordinated regional approach to growing and attracting cleantech industries. [http://tr.im/m250]

North Carolina Research Parks Network pooling marketing and long-term strategic planning resources.

Øresund IT, a regional body in Denmark and Sweden, expansive mission includes identifying and initiating R&D projects. [http://www.oresundit.com/?id=41]

World Bank infoDev project global incubator network [http://infodev.org/en/Publication.6.html]

Impacts

The risk-spreading logic behind a regional approach to technology-led development is parallel to the innovation zone strategy of universities. In their seminal study of U.S. research parks, Luger and Goldstein concluded "one of the few generalizations we can make about the net benefits of research parks is that they are far from certain." By scattering investments across a number of real estate, infrastructure, venture and human capital investments regions have more chances of success, albeit on a smaller scale, than a single bet on a research park.

Spreading risk may also improve resilience and agility in periods of economic turbulence or great technological change. The strength of regional knowledge ecosystems is that they can adapt faster than national systems, which are dictated by national politics, and they can scale up successful enterprises much more effectively that individual research parks or municipalities. In fact, one of the best models for future regional alliances may be the regional readiness partnerships pioneered by the disaster management community, which are wholly voluntary, but flexible and effective.[28]

For these reasons, it is likely that regions will become the new default starting point for formulating technology-based development strategies, with the pressure to do so coming both from the top-down and the bottom-up. National governments will increasingly delegate research funding decisions to regional networks, while a

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[28] S T Ganyard. May 18, 2009. "All Disasters Are Local" *New York Times*. Opinion/editorial.

constellation of small, local players will require greater assistance in leveraging regional assets. Regional strategies that anticipate obsolescence and disruption will permit resources to support the continuous learning of the work force and upgrading of research infrastructure.[29]

For firms, there are many potential gains from public stewardship at the regional level. The need to tap regional and global knowledge pools, research infrastructure and talent are at odds with economic development strategies that focus on particular parcels of land, campuses or local jurisdictions. Recent research on the dynamics of technology clusters points towards two important flows of knowledge that play different roles. "Local buzz" is the dialogue of rumors, knowledge and other information within a geographic cluster. "Global pipelines" are the flows of more codified kinds of knowledge that firms obtain through business relationships with distant firms. Regional knowledge ecosystems could become mechanisms that improve both functions – speeding the flow of knowledge in a regional cluster, but also making it easier for firms to import knowledge and amplify the spillover benefits to other firms in the region.[30]

Regional approaches to technology-based economic development are not without their critics however. By spreading risk, regional approaches may spread government research support too thinly across many institutions, preventing the formation of a critical mass that can achieve breakthroughs. Some innovation economists also argue that regional approaches distract policymakers from the needs of firms – and that it is individual companies that are "competitive" not regions or clusters.[31]

As regional knowledge institutions develop, and innovation zones and small research spaces proliferate, it is entirely likely that the term "research park" or "science park" will gradually fade from the vocabulary of economic development. For existing parks, the rise of regional ecosystems will require a major reinvention. It means expanding the range of workplaces they connect to and manage – in fact this will be a major value proposition for them. Park managers can play a role in helping tenants build bridges between core centrally owned space and non-core spaces like homes, cafes and airports – all the other places where people actually work. Buildings need to transform into platforms that are resilient enough to enable disruptive reconfiguration.

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[29] M Joroff, W Porter, Feinberg, C Kukla. *Enabling Work Practice (*Cambridge, MA. MIT School of Architecture and Planning, 2008)

[30] Bathelt H, Mamlberg A and Maskell P. 2002. "Clusters and knowledge: Global buzz, local pipelines and the process of knowledge creation". [http://ideas.repec.org/p/aal/abbswp/02-12.html]

[31] "The fading lustre of clusters". Oct .1, 2007. *The Economist*

PART III.
THREE SCENARIOS OF THE FUTURE

Trends are valuable for understanding directions of change in areas that will help shape the future. But the future is a complex and messy place, and will be shaped by many trends acting in combination. If we only look at individual trends in isolation, we will miss the big picture.

Scenarios are a tool for thinking about the future in all its complexity. While it is highly unlikely that any scenario we envision in the present will come true in its entirety, parts of scenarios might, and the discipline of thinking systematically about the future allows us to prepare for better decision-making in the present and near future. Some places may confront one of these scenarios more than others. Some may confront all three and have to make choices about which direction they want to go. Others may find these irrelevant but the process of systematically thinking through how they would react to them develops future thinking literacy and skills.

Four external trends were pivotal in shaping these scenarios, because of their broad importance in setting the background for technology-based economic development. They are also have a high degree of uncertainty, and may play out in a variety ways. These highly uncertain trends are:

Universities. Some universities will embrace entrepreneurialism while others reject a larger role in the economy. But all will face challenges navigating the conflicting demands and increased strains of a shifting economic and intellectual role. (see "Universities: From Ivory Tower to Economic Engine", page 25).

New science institutions. Professional societies, journals and other institutions that set the basic rules of who can call themselves a scientist, and how they should conduct research and share results, will come under tremendous strain. Something will replace these institutions, but how will it connect to existing and new places in the future? (see "Institutional Transformation", page 21)

Sustainability. The cost of energy will drive business and policy decisions across the board. How will R&D ecosystems react to different energy frameworks, and the scientific and technological challenges of battling global warming? (see "Ecological Economics Comes of Age", page 13)

The bio-industrial complex. Bioscience will supplant physics as the source of great breakthroughs, but will the fundamental flaws in systems for commercializing those discoveries be fixed, and what role will places play, if any? (see "Biology: Nature As Source and Code", page 15)

By combining plausible hypotheses about how these factors might play out in combination, we developed three scenarios for the future of research parks set around the year 2025, that are intended not to be a prediction of what will happen, but what could happen, with the goal of provoking strategic thinking about what we can do today to get ready, build resilience, and develop the ability to think systematically about the future:

Scenario 1

Science and Technology Parks 3.0

Incremental change adds up

A time-traveler from 2009 would still recognize the research parks that are being built in this scenario, all over the world, at roughly the same level as today. But looking deeper inside them, he will see that these parks are upgraded versions of their predecessors – faster, more efficient and with more features. They are starting to bring conventional tenants together with new kinds of collaborative networks, and leveraging the intellectual resources of universities more effectively than today. Put simply, they are doing some things right, but some opportunities have been passed over due to the risk involved.

Parks have developed deeper formal ties to universities and companies alike, but technology transfer is still a long, inefficient and uncertain process, and parks still play a limited role. Regional partnerships are helping to pool marketing resources and create global brands, but are not actively managing ecosystems of knowledge, talent and investment. New science networks overlap and occasionally connect to parks and campuses, but they still form and grow mostly outside the sphere of parks' influence. The most successful parks are almost exclusively housing or incubating biotechnology and biomedical R&D, and investing significant resources in bridging some of the industry's structural obstacles to innovation – though progress is incremental.

Universities as catalysts

Part of why parks haven't changed much is because universities have changed a lot. Many of the commercial and entrepreneurial functions of parks are now seamlessly integrated into campuses and curricula. Both faculty and students are supported and rewarded for entrepreneurial activity. The humanities shrink in relation to business and professional training. There has been a lot of innovation in how universities manage intellectual property and technology transfer. With private research institutions stealing away the best faculty, they really had no choice.

Parks as "living labs" for sustainability

One area that research parks have made a calculated gamble is in sustainability. The economy is still going through a managed transition new energy regime, but it has been expensive and difficult. Early on, research parks seized the opportunity to distinguish themselves as centers of experimentation in sensing, energy and resource management. A select group has pioneered its own performance standards that go far beyond LEED – they are carbon-negative and are now global centers for innovation in the booming business around managing carbon.

Bringing Biotech and Big Pharma Closer Together

The Bio Economy hasn't truly blossomed yet, due to continuing structural deficiencies in the industry's structure. But one outcome of the Great Recession of 2009 was a vastly expanded role of big pharma's strategic venture funds in financing early-stage startups.[32] In this scenario, parks have positioned themselves as strategic sites for big pharma and biotech startups to co-locate. Parks provide flexible space for both short- and long-term collaborative research projects. Parks that accommodate a wider

[32] P Mitchell. 2009. "Corporate venture funds chase early-stage deals". *Nature Biotechnology*. 27(5):403-404

range of R&D and manufacturing are attractive to more vertically-integrated bio-companies. The most successful parks are positioned as key nodes for translation between biology lab and the marketplace (and back). They have also diversified connections between science parks and universities, so that life sciences are more strongly linked than today.

A Spur on the Science 2.0 Highway

New science networks and institutions are blossoming online, and research parks and their partners are listening to and participating in these activities. But parks are not the primary places where these networks are "coming in for a landing" in the real world but not leading. The main highways of Science 2.0 pass by parks, but not directly through them. The result is that its harder for tenants to really connect to these vital communities of innovation.

Scenario 2

The Rise of Research Clouds

Disruptive competition from outside

On a sunny morning in 2015, ScienceSpaces.com went live. Targeted at everyone from angel investors to corporate real estate managers, ScienceSpaces provides a real-time global directory of available research space at small, independent incubators and pop-up labs around the world. These spaces are distributed, agile and lightweight. They pop-up overnight as needs change, and disappear when their usefulness has run out. Many are tenant-owned cooperatives.

A year later, ScienceSpaces added a rich set of collaboration and innovation management tools, providing tenants with new ways to coordinate leasing and research projects across a "research cloud" of small facilities. This model combined the scale efficiencies of traditional research parks with the diversity and dynamism of small, social collaborative research spaces.

Research parks everywhere scrambled to respond to this new competitive threat.

An Oort cloud around universities

Like the Oort cloud of comets that surrounds the solar system, invisible but carrying the chemical seeds of life, the research cloud is an almost invisible, but crucial mass orbiting research universities. Some universities find ways to leverage this, but many don't.

The universities that don't get it fail to see that they are losing their dominance as hubs in regional knowledge ecosystems. Their stodgy IP frameworks and huge cost overhead make them very uncompetitive for anything other than teaching. Their research parks are trying to re-invent themselves into the cloud, and are disconnecting from the university partners that now present more of a liability than an asset. Academic institutions remain useful as sources of labor.

Ironically, it is universities with the smallest endowments that embrace the cloud most tightly, as they are priced out of large-scale expansion. They are aggressively shifting away from the "research campus" model, and toward an "innovation zone" model. By engaging with cloud players, they can spread the risk of spin-off activities among multiple participants. Development is more incremental, with less master planning and more evolution. Extensive reuse of existing buildings will also reduce costs of housing the cloud.

A crucible for new institutions and networks

The research cloud isn't just a hub for new science and technology institutions – it is a platform for creating them. Since the cost of forming groups is basically zero, new groups are forming all the time around emerging fields of research, particularly challenging problems and new business models.

In the beginning, because it was outside the traditional system, the cloud had to invent new structures on the fly, and developed new platforms for reputation and rewards. These workplaces are peppered with sensors that "mine reality", helping the inhabitants be more effective and engineering meaningful chance encounters. But the sensors also help record people's contributions to the collaborative community. A sensor-rich environment could automagically note the 15 minutes you spent mentoring a young entrepreneur by the water cooler and credit your reputation account.

A small but growing number of research parks are injecting pieces of the cloud into their campuses, sites and buildings. These spaces are playing the role of the coffee houses of the 17th century. They are a place of open discourse among people from business, academia, startups, craftsmen, policy people, users, amateurs, etc.

Parks hobbled high-energy infrastructure puts parks at a disadvantage

Parks and universities are at a competitive disadvantage to clouds, because they have lots of legacy infrastructure, underused real estate, and are big targets for regulation and citizen watchdogs. Bioteaming becomes a popular approach for managing clouds. Research parks that are connected to manufacturing are quickly adopting industrial ecology strategies or facing public scorn.

Lightweight approaches push biotech R&D in productive new directions

While many critics thought biotech needed vertical integration, fewer networks and longer investment horizons, research clouds are showing that going in the other direction, hard and fast, can actually produce new industry structures capable of major scientific and technical breakthroughs.

Probably the biggest gain has come from the freedom clouds gain in how they manage intellectual property due to their lack of institutional legacy. Clouds make major contributions to knowledge commons like the Registry of Standard Biological Parts, and because so much of what they know is tacit, patents don't really matter that much. When knowledge leaves the cloud, it still has to be translated into something consumable by more traditional partners, but within the cloud many of those bottlenecks to knowledge circulation, that serve as barriers to innovation elsewhere, are gone.

Scenario 3

Dematerialized Innovation

Research parks in decline

In 2011, the number of research parks worldwide peaks and then begins to decline. The beginning of the end was the Great Recession of 2009, which devastated the commercial real estate industry and decimated university endowments, cutting off two of the main sources of funding for research parks. But what really spelled the end for capital-intensive parks was the Energy Shock of 2012, when a renewed global economy picked up where it left off in terms of resource demand. Virtual R&D networks made big gains during these crises, allowing companies to maintain an innovation pipeline in times of austerity, while gaining greater flexibility and lower fixed costs. During each successive crisis, this beachhead of dematerialization has expanded, and today half of all innovations come from research teams that are highly virtualized - only in the last few steps of development does any real face-to-face collaboration happen.

There are many possible triggers acting alone or in concert - high energy costs, falling R&D productivity, or a protracted global recession. Since technology just isn't solving economic, social and environmental problems, the few remaining productive research enterprises become highly virtualized to cut costs. Existing parks fail to provide value to virtual networks, and don't create local and regional systems to create sticky know-how. Research parks are obsolete, mere office parks.

Universities retreat to the ivory tower

Universities have become nothing more than very expensive coffee shops. Much of what they provide can be replicated in other places, or online through new platforms. Distance learning, which took off during the years after the recession, is now serving a large swath of the student population. DIY and peer-produced education is easy to assemble from vast learning resources online. People create and share curricula as pages of hyperlinks to archived lectures, documents and simulated learning environments.

Parks as event spaces

While demand for traditional, long-term leased private space is shrinking, the rise of distributed teams does not mean that teams never gather. On the contrary, there is a rapidly growing need for spaces that can house teams and other gatherings for a few hours, days or weeks. Some parks are re-inventing themselves as event destinations, or extended-stay research "hotels".

Costly energy pushes R&D into cyberspace

Among the many benefits of dematerialization is its much lower measureable sustainability impact. While some argue that virtualized research networks merely shift energy consumption from offices to home and from organizations to their employees, rather than reduce it, it's very difficult to prove this. Parks are at a severe disadvantage, because they are geographically contained big targets for ecological audits.

Biotechnology stagnates

Parks and universities were probably the best possible sites for housing the kind of translational bench-to-bedside research that was needed to prime the biomedical industry for rapid innovation-based growth. The failure of both to compete effectively headon with virtual R&D models means that few places exist that are well suited for translational research. Virtual networks are more suited to incremental innovation upon existing technologies. Too much dependence on virtual networks has also stifled cross-disciplinary conversations as communities of interest wall themselves off online, like radical political groups. It turns out that too much of a good thing can stifle innovation.

PART IV.
STRATEGIC IMPLICATIONS

This forecast has sought to identify the trends that will shape the future for technology-based economic development generally, and research parks specifically. Throughout Part II we highlighted tactical impacts of each of fourteen emerging trends.

In Part III, we brought these trends together to describe three scenarios for the future of research parks and technology regions. Here we highlight some broader strategic takeaways that arise from these scenarios.

Building biomedical places:
From Silicon Valley to Biopolis

Too many assumptions about how technology-led development works are based on lessons learned from the Silicon Valley experience. However, these successes have not only proven incredibly difficult to duplicate but are unlikely to be a good model for successfully growing biomedical and biotechnology industries.

More and more we are beginning to understand the fundamentally different nature of biomedical R&D, the current and optimal industry structure, and the needs of growing firms. While a place like Biopolis in Singapore has literally reframed our thinking about how to build a “city of biology”, it has by no means perfected the model. Bio-industrial regions will cluster along very different rules than IT hardware and software did. We have identified several driving forces in this study, but more focused research is needed to understand how location decisions happen in these future growth sectors.

Building responsive universities

As universities become bigger players in R&D and economic development, their relationship with research parks and regions needs to be carefully rethought. On some level, the very notion of a university as solely a center of research and teaching needs to be re-examined.

In our scenarios, universities are among the least adaptive institutions. While universities do routinely respond to market and economic shifts, they do so over very long periods of time. Today, economic development often responds to the needs of universities. For regional knowledge ecosystems to become more resilient, they will need to encourage universities that are responsive to well-articulated regional needs. Structuring these engagements around mechanisms that produce tangible benefits for the universities will be crucial.

Future business models:
from products to services

Each of our scenarios point towards a need to develop new business models for technology-led economic development efforts. The first-generation and second-generation models in use today are mainly driven by revenue from real estate development, sales and leasing and government subsidy. Potential new models are more likely to be built on venture investments, knowledge brokering and event management. The overall shift will continue to evolve rapidly from products (buildings, sites, infrastructure) to services (research “hotels”, incubation, technology transfer, knowledge commons).

Rewards for grand visions

While the Great Recession may mean the end of big real estate projects, it does not mean the end of grand visions. In fact, it is during the downtime of a recession that the window for long-term strategic planning opens most widely.

Conflicts in large-scale efforts almost always arise from a failure to reach consensus or develop a shared vision early on. So, as a point of beginning, regions need to frame and embed a grand strategy in their thinking. For example, Research Triangle Park served as a primary mechanism for sustaining a much broader grand vision of re-inventing North Carolina's economy to stem the "brain drain" of young talent leaving for other parts of the country. The park's business model, and the grand strategy of developing the Triangle region worked together over a period of several decades.

Making know-how sticky

That original grand strategy for the Research Triangle sought to address that generation's challenge of a mobile workforce – the "brain drain" migration of educated workers out of the South. But regions and places today face a different kind of mobility – of talent, but also of knowledge.

Figuring out how to create and maintain "sticky know-how" as an immobile asset will be a central challenge for technology regions and research parks. The first step is simply to assess what your "know how" assets are? What tacit knowledge is locked up in local manufacturing firms? How can strategic discussions be focused around core competence that can be upgraded and transformed rather than replaced?

Working at the very large and very small scale simultaneously

As they develop grand visions, and align interests behind them, successful regions are going to need to work simultaneously at the very small scale – unlocking the secrets of small research spaces and finding new ways to scale them quickly and coherently. Understanding the research cloud requires understanding its overall mass and shape, but also the diversity of its many fine-grained parts.

The first step in mapping this cloud will be engaging it. Identifying various elements and players in the cloud will be challenging, but we have identified many new players, groups and elements here – science bloggers, coworking spaces, angel investor networks. These can be the foundation upon which to begin discovery of the truly off-the-radar assets. The challenge will be creating venues and opportunities to bring the cloud out into the open so you can engage them.

Cultivating a regional knowledge ecosystem

Beyond visioning, there are also several possible drivers of new institutions that take on the role of knowledge ecosystem managers at a regional level. As we discussed earlier, in highly successful regions, this role is played by venture capitalists – the ultimate brokers of tacit knowledge in technology-based economies.

In aspiring regions, future ecosystem managers might:

-Support and coordinate research across a network of "boutique" research facilities

-Coordinate research among universities across a region, acting as a broker for national research funding streams

-Funding and making available major technology commercialization infrastructure (e.g. wind tunnels, supercomputing centers, etc)

-Rather than operate venture funds, invest in capacity for entrepreneurship broadly to develop the talent and high-quality startups that will attract private capital as a natural development.

Leadership for the "Long Now"

Regions need a leadership structure that can prepare for the "long now" – an extended view of how today's actions connect to future outcomes. Just like the massive science projects it will support, building and supporting regional knowledge ecosystems will require sustained, coordinated effort over many years. This is not something that will be accomplished overnight or under the influence or control of any one leadership group. This structure will need to bring about trans-generational hand off of stewardship over the grand vision, to avoid the zigs and zags that kill most plans. It won't happen accidentally, so it needs to be "designed in" from the beginning.

From managing dirt to managing activity

As research spaces become more collaborative, and the boundaries between firms, between institutions and between individuals will need to be re-designed. Places like the Network Oasis in Joensuu, Finland, are beginning to develop the tools and skills for "serendipity management". The notion of planning for chance encounters is counter intuitive, but that is exactly why it is important and why it works. Creating spaces where firms, individuals and small groups can develop new trusted relationships will be an enormous source of value creation.

Re-assessing assessment tools

There is a pressing need across all aspects of the economic development profession to develop better ways of measuring assets and outcomes, and re-thinking just what it is that needs to be measured. As we shift towards more open innovation networks and regional knowledge ecosystems, the most important things to understand will be what happens *between* institutions. But most assessment tools measure what happens *inside* institutions. In addition to understanding the scope of institutional activity, we need to map the pipelines of people, ideas and money moving through regions. The goal is to develop a vocabulary for talking about networks in detailed and specific ways, rather than the vague ways we do today.

Developing brands

Because regional knowledge ecosystems will grow increasingly complex and multi-institutional, brands will become more important, not only in marketing to outsiders but in describing just what people and organizations are doing and inspiring them to new achievements.

Today, not many regions do a good job at brand management. In the future, building a brand as an identity that can describe and communicate the unique value of a knowledge ecosystem will require active cultivation on an ongoing basis. The "grand strategy" discussed earlier can be a powerful tool in testing and maintaining consistent and effective brands.

Brands will be crucially important in attracting globally mobile talent and earning reputation in new group economies.