IRI2038 Futures Study

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FOREWORD

In February 2014, the Industrial Research Institute (IRI) entered its 76th year as the only organization acting to strengthen innovation management across all industries. The hallmark of our service has always been the focus we put on practitioner-driven and practitioner-oriented research on the cutting edge of technological innovation management. In fact, some of the most important concepts in today's innovation leadership benefited from their early exploration by IRI members and presentations at IRI meetings –these include what are now known as StageGate®, Open Innovation, and the Fuzzy Front End.

Over the years, our Research-on-Research (ROR) working groups have been the cornerstone of our efforts to enhance the effectiveness of research and technology management. By calling on the collective creativity of our membership, our working groups have effectively addressed some of the greatest challenges facing R&D managers worldwide. During our 75th anniversary in 2013, IRI chose to exploit our research capabilities in order to enter entirely new territory.

The themes for our anniversary were: Celebrate, Impact, and Envision. The past and present were easy enough: look to all that IRI's members have accomplished since 1938 and it is not hard to recognize the brilliance of these organizations and their R&D staff. The future, of course, poses a different challenge – we don't know the future. However, IRI does have a unique ability; we can pull together innovation leaders from around the world, in all industries, to gather their perspectives. Ted Farrington from PepsiCo had just completed a Foresights Study for his organization and knew that this methodology, combined with IRI's research abilities, could create something extremely powerful – the development of plausible scenarios of the future of innovation leadership.

The IRI2038 Futures Study is the largest and most expensive research project IRI has ever undertaken. Ted Farrington of PepsiCo must be recognized and thanked for the extensive work he put into overseeing this project from start to finish. Christian Crews of AndSpace Consulting is also owed much gratitude for his insight in proposing and establishing the framework for this project as it moved forward. And of course, Lee Green, IRI's Senior Director of Research and Thought Leadership, is greatly appreciated for shepherding the project to a successful conclusion after picking it up midstream from Jennifer Blenkle. Thanks also to the other members of IRI's staff for their dedication and patience in assisting this project at every step.

As you read through this report, keep an open mind and enjoy the thought-provoking possibilities such futures may offer. When you finish, I hope you will consider the tremendous benefits of conducting your own foresights project.

Sincerely,

Ed Bernstein
President
Industrial Research Institute, Inc.

INTRODUCTION

At IRI's November 2011 Member Summit in New Orleans, I had the opportunity to give a plenary lecture on a project we had done at PepsiCo entitled Research Foresights. Our project explored the use of Strategic Foresights methods such as Implications Wheels, Inductive Scenarios, and Participatory Futures to inform our project portfolio for longer range research. As I left the podium, Martha Malone, IRI's VP of Education, approached me and asked "Would you consider leading a project like this as part of IRI's 75th anniversary in 2013?" I answered in the affirmative; thus began the two-year journey reported in this book.

You will not find the word "prediction" used anywhere here to describe the IRI2038 project. That is because strategic foresight is NOT about predicting the future. Strategic foresight is about developing provocative, yet plausible, alternative views of the world in which we find ourselves so we can investigate them and better prepare for the real future as it unveils itself.

Any good foresights project needs a clear focus question that can be used to guide the effort and prioritize results along the way. The focus question for IRI2038 was:

"How might future trends, developments, and events impact the art and science of research and technology management over the next 25 years?"

The IRI2038 Futures Study examined hundreds of trends, weak signals, and implications on its way to developing the four future scenarios reported in this book. Frequently, themes emerge across multiple scenarios, suggesting that we should pay serious attention. After completing the project and having some time to reflect, here are my top ten potential future trends, signals, or themes that, for me, stood out the most, in no particular order:

1. **The Hollywood Model** – With the technical workforce largely freelance 25 years from now, the job of an R&D leader will look more like that of a Hollywood producer as a new crew will need to be cast for almost any research project.
2. **MOOG's Everywhere** – Massively Open Online Games such as "The World Without Oil" and "Innovate2038" will become routine events designed to engage the entire organization's collective intellect to solve problems of real importance.
3. **Crowdsourced Funding** – Many companies will crowdsource a portion of their R&D budget and use it as a component of portfolio management.
4. **Augmented Humans** – Half the resumes coming across a hiring manager's desk may be from individuals who have done something to artificially enhance their physical or mental capability to better match the job requirements. What will be the implications for human capital management?
5. **The Era of Women** – With the underrepresentation of women in some areas of science and engineering finally behind us, how will their increased presence in senior R&D roles impact the management of research and technology?
6. **Cognitive Computing** – Future versions of IBM's Watson computer will analyze all available data to answer even the most complex questions, ending data overload but ushering in the era of knowledge overload.
7. **OI Becomes a Sellers' Market** – Open Innovation (OI) will change from the current buyers' market to a sellers' market, with OI partners choosing with whom they work based on the organization's reputation as a partner of choice and how easy it is to work with.
8. **Nurturing the Innovation Ecosystem** – A large portion of the R&D executive's time will be spent nurturing an innovation ecosystem made much more complex than today with new innovation entities and the freelance workforce.

9.   The End of the Patent – For many industries, speed-to-market will replace traditional intellectual property as a basis for competition.
10. The End of the Time Zone Problem – While you are sleeping, your intelligent avatar will sit in that midnight meeting with headquarters, giving you a download the next morning.

Such are the provocative insights you will glean from reading through this futures study. This book leads with results, describing the scenarios as well as the Innovate2038 MOOG's results and conclusions in Section I. Section II describes in detail the processes used to develop and analyze the scenarios, including all the trends, signals, and implications found along the way. Depending on whether you like to build up to results gradually or jump to them first, your reading can start with either of these two sections. Either way, I hope you enjoy the results as much as we enjoyed undertaking this project.

In acknowledging those who made this project a reality, I must first thank Christian Crews of AndSpace Consulting; my guide through several strategic foresights projects. He has taught me to view foresights as a process, not as an event. The four phase approach (Discovery, Extrapolation, Integration, and Planning), taken in all our collaborations, is his creation.

Many thanks also to IRI's leadership and member sponsors who supported the 75th Diamond Jubilee and made this project possible. Special thanks go to IRI's President, Ed Bernstein, who trusted Christian and me with what became the largest project ever undertaken by IRI.

Thank you to the hundreds of IRI representatives and many others outside IRI who participated in our workshops, interviews, and online game, or contributed trends and signals to the project directly.

Many thanks to my management at PepsiCo who supported me while I undertook this endeavor.

Finally, the greatest thanks go to my wife, Gail, who encountered some serious health issues while this project was underway. She encouraged, inspired, and expected me to keep going and to bring IRI2038 to a successful conclusion.

It is my honor and privilege to have led this unique and exciting initiative.

Ted Farrington

Ted Farrington
Senior Director
PepsiCo Advanced Research

SECTION I:
IRI2038 Futures Study, Research, and Scenarios

Chapter 1:
A Journey into the Future of R&D Management

In 2012, we had a great opportunity. We held the master plan for celebrating the Industrial Research Institute's (IRI) 75th anniversary—our anniversary—in 2013. In it was a plan to establish a vision of the future of research and development (R&D) management. We wanted to go big. We wanted to help our members stay competitive in a changing R&D landscape. As a result, we launched the **IRI2038 Futures Study** to assist our members in making the best strategic decisions for the future of their organizations. It was the biggest project we had ever undertaken in our 75 years.

This is the story of our journey.

How does one envision the future of R&D management? While it is true that R&D differs by industry, all industries face similar challenges when *managing* R&D professionals and processes. And, despite the lack of a coherent "future of R&D" there is a method to explore the "future of R&D management" in a structured way called Strategic Foresights, which results in multiple views, or scenarios, of the future in which we may find ourselves managing R&D.

While it is true that no one can accurately predict the future, we may, nevertheless, develop potential scenarios based on evidence visible today. We began with a baseline view of the future accepted by most R&D practitioners. We collected a variety of signals of change, which may or may not occur, that could shift our baseline view. The multiple narratives that emerged from those potential shifts formed the structure of our research.

Interestingly, there are a few results that are common across all of the scenarios, but the majority of them are not. To assist us in categorizing the latter, we developed four areas of impact that would act as special lenses through which we would view our findings. These four areas were Project Management, Portfolio Management, Talent Management, and the Value Proposition of Research. These lenses helped us shape the framework for analyzing our research findings to ensure that our results would be relevant to our members. Part of the power of inductive scenarios such as these is that they can also be explored through other lenses. We encourage readers to interrogate the scenarios from other perspectives, such as "What do these say about the future role of a Chief Technology Officer (CTO)?" as one example, among many others.

Foresights research is an ongoing process of building a framework, i.e. scenarios, and then using it as a tenuous baseline for us to reference in strategic planning sessions over the coming years, perhaps decades. The framework can be continuously updated and serve as a product in its own right, and one that will remain a valuable resource for us and for our members so long as we continue to build on it.

It should be made clear that foresights scenarios, such as those developed by IRI2038, are not predictions. These scenarios are designed to foster more fruitful dialogue during strategic planning. Through the exploration of multiple foresight narratives, participants gain valuable insight and a better guide for approaching and developing a step-wise strategic vision. The primary deliverable at the end of such a project is a backcasting exercise that allows participants to step into the future 25 years hence and work backwards, asking what they and their organizations will need to do 25, 20, 15, 10 and 5 years out from the current day to be successful in each scenario. As the true future unfolds, relative priority among the scenarios is adjusted.

Foresights Data Collection Toolkit

Foresights research is similar to piecing together a mosaic. It starts with the collection of a broad spectrum of smaller pieces. The futures study team then puts these pieces together to form a larger picture (e.g. a foresight scenario) through a series of workshops. The IRI2038 leadership deployed the use of four tools designed to collect and sort these fragments in the construction of its scenarios. This foresights data collection toolkit is comprised of a Futures Audit, an internal retrospective study of past literature and past association projects, a Weak Signals Environmental Scan, and Implications Wheels. Each of these will be explained in more detail in Section II.

Briefly, the Futures Audit involves personal interviews with R&D practitioners, technology experts and futurists. The purpose is to identify common themes and trends they agree are likely to happen. The retrospective helps refine these results by looking at what types of questions and projects were investigated over a similar time period just prior to the one under investigation. A Weak Signals Environmental Scan seeks out emerging trends, or weak signals, not on everyone's radar that could disrupt the consensus view of the future obtained from the Futures Audit.

By definition, these trends and weak signals can be found today. Future scenarios must be built from future implications and impacts of these current day data. Implications Wheels, a foresight tool developed by Joel Barker, serve this purpose. Selected trends and signals are assumed to grow and implications wheels develop multiple first order, second order, etc., possible future impacts for each. These future impacts become the data from which our scenarios evolve.

Chapter 2:
IRI2038 Foresight Scenarios and Implications

The Futures Audit interviews identified 84 distinct past, present, and future drivers of change in research and technology management. Twenty-two are discussed in detail in the Futures Audit report and ten of these were brought forward to the next stage of the project. The Environmental Scan added 23 weak signals to the list obtained from the Audit. Each of these tools and their results is explored in more depth in Section II.

From the findings of these foresight data collection tools, Implications Wheels were then employed during working group sessions, allowing participants the opportunity to follow the implications of an identified trend or weak signal to potential second and third order impacts.

The IRI2038 scenarios evolved from workshops held at the 2013 IRI Winter Research-on-Research (ROR) Meeting. Four parallel workshops developed "influence diagrams" identifying possible connections between future impacts of the identified trends and weak signals. Over the following several weeks, the project team turned these diagrams into systems maps and the inductive scenarios presented below.

At our 2013 Annual Meeting—our 75th Anniversary Diamond Jubilee—two sets of four parallel incasting workshops were conducted where participants were asked to immerse themselves in the scenario as if they were living in it, then the facilitator probed to deepen their thinking about living and working in that future. Facilitators and participants discussed the impacts the scenario would have on the art and science of research and technology management given the assumed changes, as well as what they would need to do to be successful in each future.

Features Common across All Scenarios

Despite four very different scenarios being developed with many unique areas of impact for research and technology management, a few themes emerged that were common across them all.

Simulation and AI for Project Management
All four scenarios see an increased use of computer simulation and artificial intelligence (AI) in project management. Researchers on simple execution projects will feel like they work for AI systems while advanced simulation and cognitive computing drastically increase the rate of success for high potential – high risk projects.

More Open Innovation than Today
The innovation ecosystem will be much more open than today, driven by the largely freelance workforce and formation of new innovation entities beyond the universities and laboratories we collaborate with in the present. Companies will routinely leverage each other's supply chains for speed-to-market in arrangements more complex than anything we see today. Project managers will need to master these complex relationships to be successful.

Intellectual Property
The role played by the traditional patent is diminished in every scenario, but for different reasons. Speed-to-market may be more important; the extremely open nature of research may make them impractical; the project portfolio may comprise many small projects; or, product lifecycles may become very short. All of these reduce the patent's value. While this is clearly dependent on a given industry's rate of change, many will need to find other means to compete and recoup R&D investments.

External Talent Management
Driven by the freelance workforce, all four scenarios see R&D leaders managing a talent pool that is more outside the traditional corporate walls than internal. The most extreme case is the Hollywood Model within the Three Roads to Innovation scenario where essentially all projects are executed with temporary technical staff. Significantly more R&D managers' time will be devoted to cultivating this external talent and marketing the managers' R&D organization as the place to work, temporarily.

R&D's Changing Value Proposition
That R&D's value proposition will change is common to all scenarios, although the changes are scenario specific. Speed-to-market will be more valued than long-term Intellectual Property in several cases while connecting the all-powerful mega-cities with the right innovation partners becomes R&D's role in one scenario. Other valued roles include the very early identification of consumer trends and knowing when to leverage external vs. internal innovation resources. The one certainty is that R&D's role, and therefore its value proposition, will change.

How to Read the Scenario Narratives
The following four inductive scenarios were built through a lengthy process of collecting, analyzing, extrapolating, and integrating data about plausible futures and the forces that might shift these futures in multiple directions. Inductive scenarios use systems thinking processes to emerge from analysis of future implications of the trends and weak signals. Graphically they appear as 3 to 4 interacting subsystems, typically each a closed system itself. Every scenario is reported in similar fashion:

- A single paragraph abstract giving each scenario's key feature.
- Detailed description of the subsystems involved.
- Scenario Analysis – what's valued in each scenario?
- Implications for R&D in terms of Project Management, Portfolio Management, Talent Management, and R&D's Value Proposition.

Citations are provided that allow each scenario's elements to be traced back to their original trend or weak signal within this report.

These narratives are not built in linear fashion. The story arc of each explores possible shifts that may occur due to how various weak signals and their implications affect the global business environment. As a result, the forward movement of the narrative may not have a perfect causal relationship, but instead contains a dialogue on how various trends and weak signals interact with one another within an agreed-upon baseline future.

Detailed descriptions of the Futures Audit's 22 global drivers of change and of the 23 weak signals identified during the Environmental Scan can be found in Section II. A simple view of the third order impacts constructed during the Implications Wheels can also be found in Section II.

Scenario 1: Africa Leapfrogs Developed Markets

"An inability to build new capacity in the developed world due to increasing environmental regulations creates a new flexible and localized manufacturing process. This process churns out the highly customized products consumers demand at an ever-faster pace. With less of an installed asset base and the ability to better leverage its natural resources, Africa jumps ahead of the developed world in growth and economic dynamism."

— Excerpt from the <u>IRI2038 Scenario Report</u>

The scenario in which Africa is forecast to overtake developed markets emerges from a working group that analyzed second and third order implications stemming from these Futures Audit trends and Weak Signals:

- <u>Simulation</u> technology advances;
- A business environment experiencing increasingly <u>constrained access to resources</u>;
- The emergence of a <u>Zero Waste Society</u>;
- A shift in our relationship with the natural environment known as the <u>Rise of the Lorax</u>;
- The growth of cities as well as international and regional bodies, leading to the <u>Withering of the State</u>;
- <u>Crowdfunded R&D</u> and the changes it brings to funding research;
- Economic and geopolitical trends that many believe will lead to the world <u>Serving a Rising Africa</u>; and,
- Ubiquitous connectivity concerns here labeled <u>"Islands in a Connected Stream."</u>

With future impacts derived from these trends and signals as starting points, the narrative developed as participants identified interactions and simple systems comprising them.

A New Manufacturing Model

For starters, the working group participants felt that diminishing raw materials was not the only factor to affect global resource constraints. The world is increasingly changing its environmental paradigm to one in which its relationship to the natural world is equalized. For example, countries such as <u>Ecuador</u> and <u>Bolivia</u> granted equal rights to nature in 2008 and 2010, respectively, and project participants expect this trend to continue over the next two decades as more countries join the movement. By 2038, it is assumed that access to raw materials will become diminished as a result, preventing companies from exploiting any new land for mining, farming, or manufacturing in the developed world.[1]

Organizational efforts, therefore, turn to improving the efficiency of existing assets, and competition is expected to become fierce as a zero sum environment emerges. Participants expect this to give rise to the extensive use of 3D printing and "de-printing"—the ability to disassemble finished goods and re-use their materials in printers to create new products.[2] The <u>Zero Waste Society</u>, a trend resisted by most companies, gradually generates national and international legislation for "cradle-to-grave" ownership over products to increase corporate responsibility. Despite such legislation being initially perceived as a financial and regulatory burden, it eventually becomes beneficial to companies operating with limited access to raw materials.

With the gradual transition to "cradle-to-cradle" (C2C) legislation, legal ownership over used products becomes a boon to industry, but in name only. While a portion of discarded products return to producers, who own the nominal rights to their products even after they are thrown away, a network of flexible, small-scale 3D manufacturers begin acquiring discarded products from competitors and de-printing them for their own use.[3][4]

The main conclusion drawn from this initial analysis assumes the eventual rise of a new manufacturing model in which companies own the nominal rights to all of their products and have stronger control over the natural resource chains they employ. However, the tight, zero sum grip companies have over resources is undermined by the rise of a flexible, 3D printing, black market. This creates a bifurcated global manufacturing model of large-scale companies competing against small, agile manufacturers churning out new products en masse from the materials "borrowed" from existing products.

A Hyper-Competitive Churn

Given the constraints on materials and energy, more accurate knowledge of customer wants and needs becomes critical. Companies spend large amounts of time and money mining massive data sets and performing ethnography to surface consumer needs ahead of competitors. Additionally, as the process of urbanization continues, major cities eventually have the populations that countries used to have, which allows companies to create and market to very specific regional differences, assuming they can find them in their massive databases.[5]

The success rate for new products skyrockets as small companies receive funding for new products directly from prospective customers.[6] These new products are displayed in retail locations, but only as samples.[7] All purchased products are 3D printed locally and delivered to the customer on the same day as purchased. Consumers become accustomed to a relentless churn of new products, each new one more targeted to their needs than the last.[8] But soon no product is ever good enough, and consumers become conditioned to constantly seek novelty.[9]

In such a competitive economy, companies realize advantages must be kept as secret as possible, and many either return to private status, or never go public in the first place in order to avoid the onerous reporting required and the regulations that force companies to give potentially competitive answers to shareholders and analysts.[10] Because the new 3D printing flexible manufacturing infrastructure is relatively cheap to use, companies can afford to stay private and do not see the need for public shareholder funds.

A Rising Africa

As natural resources become constrained in developed countries, Africa's unleveraged farmland, minerals, and fossil fuels become a critical world resource.[11] Africa is able to avoid the hyper-competition of the developed world by making more effective use of its natural assets. Countries in Africa begin by re-nationalizing resources being developed by outside companies and countries. Chinese and other Western interests are suddenly locked out of exploiting African resources.[12] African countries then form larger "resource empires" that become the "greater federal Africa," a sub-Saharan collection of African states that operate on a single currency and set of commerce laws.[13] Unsaddled by legacy power grids and factories, Africa leapfrogs the West in the development of the new economy.

Massively Open Online Courseware (MOOCs) also allows African students to excel in the sciences by having access to the best educators in the world at virtually no cost. A new generation of highly educated Africans self-organizes in Accra, Ghana, and by 2038 the network of skilled labor, money from natural

resources, and companies unencumbered by high manufacturing assets has created the equivalent of Silicon Valley, but moving at twice the speed.[14]

African companies compete with lower costs, higher transformative innovation from younger engineers and scientists, and the ability to sell innovations from Africa to increasingly poorer developed economies. The center of gravity for innovation then moves to Africa, where funds and tolerance for big transformative innovation grows, as opposed to the developed economies rapid churn of incremental innovation.

In both the developed and the developing world, however, the middle class has all but evaporated.[15] There are many more wealthy individuals who are owners of small private companies printing out all kinds of products for consumers. At the same time the services economy grows dramatically for low-paying jobs to serve the new natural resource kings and Accra wealthy.

Scenario System Architecture

IRI workshop participants examined how third order impacts of drivers and weak signals of change from the Futures Audit and Weak Signals Environmental Scan would interact to influence each other. The following diagram served as the baseline for the construction of the above narrative.
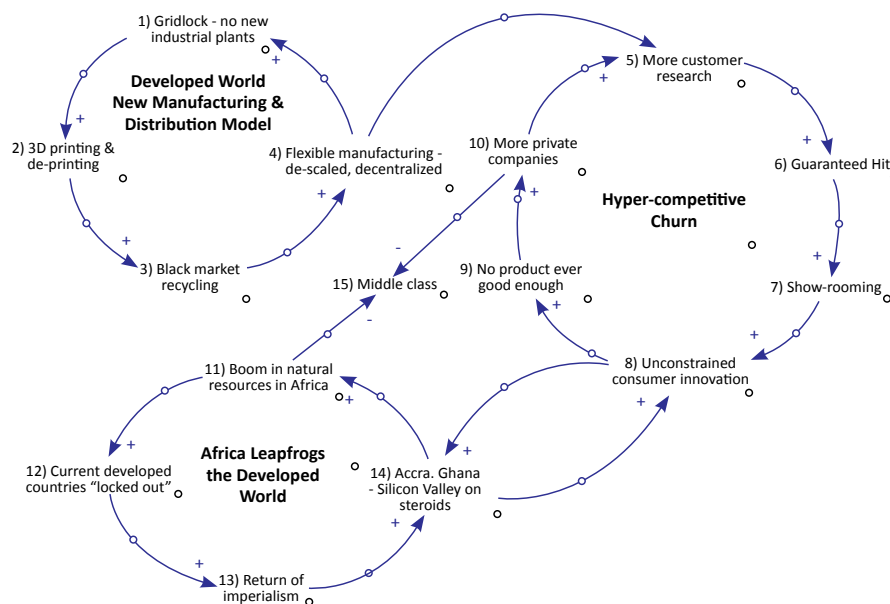
Scenario Analysis

The value system in this 2038 scenario is not much different than today. Aside from strict environmental regulation in the developed countries, the world is still driven by consumer demand and consumption. This scenario is characterized by incredible market speed, fueled by hyper-competition in a shrinking market and cutthroat capitalism from Africa.

The youthful energy of Africa, unharnessed by an almost-free, world-class education and rapidly expand-ing economy, develops transformational innovations characteristic of young inventors and entrepreneurs. This is tempered by the developed world's older scientists and engineers, who excel at integrating this future's mix of Big Data, distributed manufacturing, and limited resources.

Throughout this churn there is little room for a middle class. With much lower requirements for workers, owners and private shareholders of small companies can compete with any company worldwide. Society bifurcates between owners of companies and natural resources creating value, and the service workers that support them.

Implications for R&D Management

Discussion during the development of this scenario focused on four areas of impact: Project Management, Portfolio Management, Value Proposition of Research (to companies and society), and Talent Management.

- **Project Management Implications**
  Participants defined project management as the complex work of integrating myriad parts into a whole. This scenario anticipates projects getting distributed across many parts within an organization and with other companies, contractors, and free agents. Projects are extremely agile, and aligned with a "fail fast, fail cheap" mentality. Much of conventional project management is replaced by software as the work is broken into many discrete tasks, bid out, and outsourced. Central project management software manages and integrates information digitally and automatically, with speed paramount. Human project managers, therefore, will oversee a model, not its many parts.

- **Portfolio Management Implications**
  Similar to project management, participants felt portfolio management would largely disappear. As intellectual property protection dwindles to the process of making things, not the things themselves, humans become operators of a large software management program. Simulation dominates decision-making. Initially these simulations are purely operated on silicon computing platforms, but over time more biological systems arise to handle simulation complexity.

- **Value Proposition of Research Implications**
  Given the speed of changing consumer demands and the open nature of collaboration, research becomes a service offering to customers who need the capacity to keep pace with their consumers. Competitive advantage comes from the speed of research to provide cradle-to-cradle product design, not in long-term intellectual property protection.

- **Talent Management Implications**
  The focus for talent management shifts to renting, not owning, the workforce. Managers will need to work with guild-like talent pools to have the right expertise on-demand for fast-moving projects. As such, talent management fades away and is replaced by a sourcing department that maintains external relationships and excels at finding critical skills when needed.

Overall, there will be far more AI support for the research and technology function. As the speed of busi-ness continues to increase and the shifting needs of the consumer become paramount, managers will be focusing on tending the overall process software and making decisions on focus, while intelligent agents do much of the project and portfolio management heavy lifting. The need to understand the global nature of the workforce, and the rising cultural trends common to sub-Saharan Africa as it gains in prominence, will also feature into how talent and project managers handle R&D.

Scenario 2: The Death of Distance vs. Mega-Cities

"Smart cities and resource constraints force a political and economic restructuring of the world. Cities become the major political force in countries due to their embrace of smart technologies to manage transportation, energy, and waste. They grab natural resources through giant public/private partnerships and grow into city-states. Technology and connectivity make distance irrelevant at last, restoring some balance to individuals and enabling scientists to do and teach at the level of entire corporations or universities of the past."

— Excerpt from the IRI2038 Scenario Report

A trend visible to anyone in today's workforce is a person's ability to telework. Technology and connectivity are key themes of the IRI2038 foresights scenarios. The global drivers of change from the Futures Audit and Weak Signals Environmental Scan which form the baseline of this scenario are:

- Advances in Robotics and Automation;
- Resource Constraints;
- The development of a Virtual R&D Workforce and Labs;
- The growth of cities as well as international and regional bodies, leading to the Withering of the State;
- A growing importance placed on Nurturing the Data Supply Chain;
- A shift in our relationship with the natural environment known as the Rise of the Lorax;
- The Anthropocene Epoch, when humans begin tinkering with the planet/climate;
- A rising capability for, and implications of, Human Augmentation; and,
- Neural mapping allowing researchers/marketers to Perfect Persuasion.

Participants started with the assumption that raw materials for products, and food and water for people, will be harder to find, develop, and deliver to a burgeoning global population. This is assumed to create opportunities for research and technology management to find unique solutions. The ability to automate experiments and use robotics to accurately perform repetitive and precise work was agreed on at this point and brought with it the expectation that researchers would be free to spend more time on analysis. The growth of online lab space also allows researchers to collaborate without sharing actual office space, creating more diverse project teams and lowering overhead.

The narrative emerging from this scenario, however, used a variety of third order impacts from the Implications Wheels to show how the use of data analytics and advanced AI may create a two-fold model. In this model, individuals choose not to telecommute simply because of its availability, but also as a response to the way data might be used to streamline the operation of the newly emergent mega-cities that some perceive as invasive.

City Planners Seize Control with Data

In this scenario, the city became the locus of political energy to solve many of the transportation, energy, and waste issues in society. With smart technologies such as sensors, cameras, and data analytics, cities can knit people, infrastructure, and regulation into tightly controlled networks. Each city forms its own unique culture that companies must serve as individual niche markets.

Workshop participants saw smart cities grabbing economic power as their individual markets became very large and important to multinational companies and the countries in which they reside. In this process, it

is assumed that city planners and corporate marketers will collect and analyze massive amounts of data about the behavior of residents. Individuals whose actions are marked as statistical bellwethers by marketers become sought after commodities for their personal information, buying habits, and opinions.

Mega-Cities Dominate Resources and Lives

As smart cities eclipse the countries in which they reside, they annex land, create land along their coastlines, and grow their populations.[19] They go to great lengths to secure resources for their citizens, going into energy and commodities markets with large buys that lock out others.[20]

To further their control they form giant public/private partnerships with international companies and other municipalities to terraform living areas and artificially manage local climates.[21] Society separates into two groups: those who are politically and economically empowered by the data driven city-state, and those that serve them.[22] The traditional middle class shrinks significantly.

MOOCs Level the Playing Field

Slowing the complete domination of the city-states are the advances in robotics and automation that allow knowledge workers the ability to work anywhere in the world, thereby avoiding urban residence.[23] This remarkable death of distance extends to education, providing anyone in the world with access to the top professors to learn what is needed, when it is needed, through remote, competency-based Massively Open Online Courseware (MOOC) systems.[24] Supported by expert software systems approaching full Turing status,[25] the most successful scientists effectively teach hundreds of thousands of students a year and become cultural celebrities.[26]

That same technology frees enough time and independence to also allow them to freelance on projects to multiple companies at any one time. The best scientists are in high demand and command the salaries of sports stars. Also furthering the death of distance, a Nobel Prize is expected to be awarded to the scientists who invent a way to deliver all sensory experience remotely to someone through a virtual presence.[27]

Citizens Fight Back

The virtual sensory experiences can be recorded as well, paving the way for more and more people living their lives virtually to store every memory in the cloud. These memories are backed up and accessible to their owners anywhere and they can even be shared with selected people.[28] The aging societies around the world adopt the behavior of compulsively storing their memories online to continue to be productive at work and keep up at home.

However, they are concerned about the power of the mega-cities and adopt counter surveillance techniques to ensure that the powerful governments have only a limited view of their behavior.[29] These measures include necklaces that blur their features on CCTV cameras, encoded smartphone transmissions, and highly complex authentications for accessing personal memories and other information stored in the cloud. This reduces the power the mega-cities have over citizens and begins to restore some personal liberties.

Scenario System Architecture

IRI workshop participants examined how third order impacts of drivers and weak signals of change from the Futures Audit and Weak Signals Environmental Scan would interact to influence each other. The following diagram served as the baseline for the construction of the above narrative.
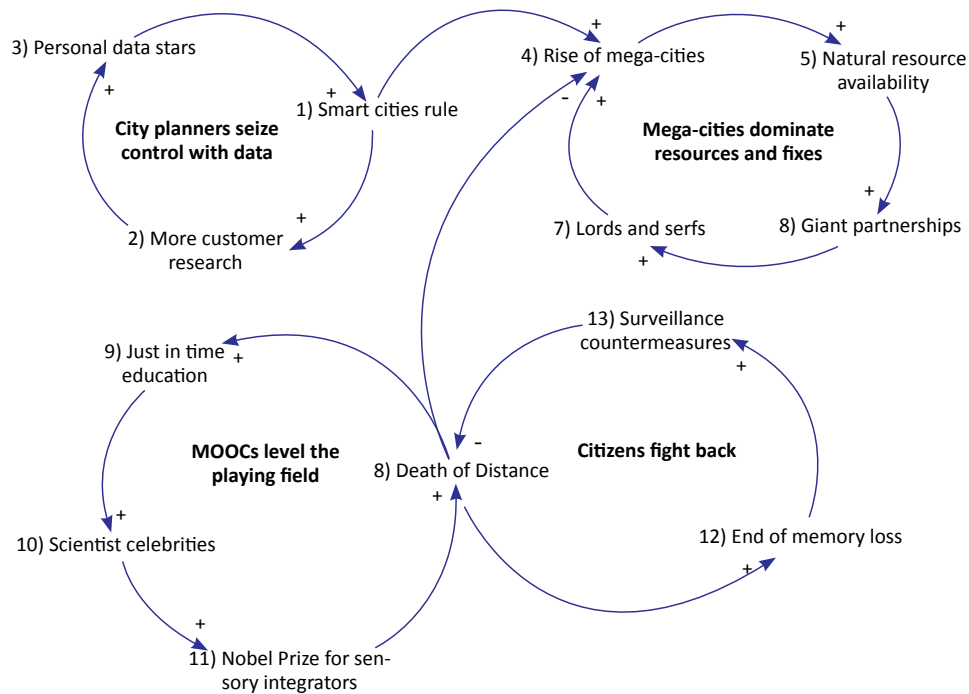
Scenario Analysis

This scenario represents a significant re-ordering of the political and economic systems of the world. These include the rise of technology-enabled super cities that use data to highly choreograph the lives of their citizens, and new public/private partnerships that blur the line between governance and commerce. The scenario also suggests that these cities are engaged in large geo-engineering projects that are altering the shape of the physical geography of human environments. Some of these projects are about halting the effects of global warming to keep a status quo, and other projects are building new habitats for people such as artificial islands.

Such technology has also empowered individuals, however. Against the power of the neo-feudal city-states are the celebrity scientists, who can leverage the MOOC platform to reach hundreds of thousands of students and command large salaries from the highest bidders for their temporary services. Ordinary citizens

are also actively engaged in limiting the power of the city-states by protecting personal data and behavior as best they can.

This scenario values the exploitation of people, machines, and the planet for the most efficient outcomes. There is a rising ascendancy of the virtual over the real, but most continue to choose to live in cities despite the freedom that the death of distance provides. This urban culture drives a robust economy unique to each city.

Implications for R&D Management

Discussion during the development of this scenario focused on four areas of impact: Project Management, Portfolio Management, Value Proposition of Research (to companies and society), and Talent Management.

- **Project Management Implications**
  An increase in the number of micro R&D projects within companies or across companies working for the city is indicated. The ability of the manager to quickly commission these smaller projects is critical. Team assembly, especially for projects that require a number of experts from different disciplines, becomes the core competency for R&D managers.

- **Portfolio Management Implications**
  Research portfolios are driven by the mega-cities organizing and funding R&D to meet their needs for products and services. The portfolio is populated by crowdsourced projects that mobilize guilds and stratified workforces with a few key idea people at the top. The value of intellectual property is in synthesis/integration of projects better aligned with the city's social needs, such as providing a 100% renewable path.

- **Value Proposition of Research Implications**
  R&D becomes the tool for the city's open innovation machine. It provides highly quantitative and instant research to the city by utilizing masses of people in an open innovation framework.

- **Talent Management Implications**
  The reputation market, and the feedback score of individuals, defines the new meritocracy. The system encourages the evolution of superstars, but the technical base for the whole workforce has been raised. Compensation goes beyond money and includes the city's amenities, like choice places to live, commodities, and additional resource allocations.

Overall, the mega-cities will replace corporations as the main clients for research and technology management. Managers are mobilizing workers from many different companies and universities to solve city issues in open innovation platforms. Often these projects are small and build on each other toward a larger goal, so managers need to guide projects and stakeholders to build on previous work and teams.

Scenario 3: Three Roads to Innovation

> *"Society chooses three paths toward innovation in an era of virtual work and prize driven motivation. Many choose to directly connect their brains together in a community in which the network runs project management. Another path is to intentionally form insular communities to work in secrecy and prevent outsiders from obtaining their intellectual property. Many corporations travel a third path to maximize creativity and minimize risk by adopting a model similar to Hollywood movie studios, where a small production team manages a large pool of freelance talent."*

— Excerpt from the IRI2038 Scenario Report

The previous two scenarios dealt with ways that resource constraints and advances in data analysis may affect social, political, and economic structures worldwide. This scenario was developed when workshop participants analyzed the following trends and weak signals from the Futures Audit and Environmental Scan:

- Advances in Nano- and Bio-Technology;
- The development of a Virtual Workforce and Labs;
- The rise of Freelance R&D workers;
- The capability for, and implications of, Human Augmentation;
- The popularity of Open Source Science;
- An ascendant Era of Women;
- Concerns over ubiquitous connectivity called Islands in a Connected Stream;
- Neural mapping making way for Perfecting Persuasion among marketers; and,
- Reverse Management Innovation.

With future impacts derived from these trends and signals as starting points, the narrative developed as participants identified interactions and simple systems comprising them. Participants assumed that nano-technology and biotechnology will finally fulfill their promise and become major platforms for innovation and growth. In this world, R&D becomes highly distributed, with teams hired for short-term projects who meet virtually to perform the work. In the process, individual views of trust and identity are challenged, and wealth provides differing layers of access, resulting in the growth of three separate types of innovation community.

A Community of Brains

With the advances in nano- and bio-technology, participants expected human modification efforts to get ramped up, but with only a fraction of society capable of purchasing them. A divide occurs between older, wealthy people—who can afford the longevity solutions—and everyone else.[30] In order to protect themselves from dementia and other cognitive diseases associated with aging, the healthy wealthy increasingly choose to connect their brains wirelessly to the cloud.[31] Working together, these connected brains use new sensory equipment to perform experiments and to innovate new products and transformational new sciences. This equipment includes directly sensing electromagnetic fields, seeing beyond the visible spectrum of light, and measuring time and distance automatically.[32]

Individuals with network connected brains record and upload every second of their lives and make those experiences accessible to other brains in the same network.[33] Participants in this workshop then saw a meta-intelligence potentially emerging from this development as the interconnected community expands and learns; each single brain would act as a neuron in a much larger collaborative intelligence. Project managers disappear as the network itself develops intentionality and manages projects as a reflex. As these powerful

networks of brains seek to solve harder and harder problems, they participate in open innovation challenges that award significant prizes to teams that find transformative solutions for companies or social issues.[34]

Innovation Tribes

The "Prize R&D" effect also drives another form of innovation done by those financially unable to afford the bio and nano enhancements of the healthy wealthy, or who simply do not wish to participate in the networked brains. These people will only work closely with others they highly trust, and share information and knowledge behind complex firewalls and in single physical locations.[35] Companies and some online communities migrate to this form of innovation, sequestering people together with servers walled off from the outside world. With read-only access to the internet, these new skunkworks organizations win prizes and create products for easy nano-assembly that are transformative and lucrative.

As this form of innovation becomes successful, IRI2038 workshop participants felt that such closed off "tribes" could become an option for many people in the sciences when embarking on a career. Almost like joining a sorority, the process of choosing an innovation community involves finding or creating with others in a physical location where like-minded people live and work together. In addition to working together to develop new products or win open innovation challenges, these high-trust intentional communities share childcare and other services.[36] Intentional innovation communities become a top choice for women who wish to balance the demands of a professional life in the sciences, or politics, with the realities of raising a family.

To protect themselves from the outside world and keep their intellectual property a secret, intentional community members are also expected to mask their behaviors in online and physical locations. Companies and governments learn little about these communities because citizens blur their faces in CCTV cameras and encrypt their communications and payments.[37]

People in this scenario are assumed to live in fear of what new flu virus or self-replicating nano-materials might go out of control. Because these secretive communities are difficult to regulate, governments attempt to restrict access to public labs and to advanced bio or nano equipment.[38] This only spurs more people to join these innovation tribes and escape the invasive government controls.[39]

Hollywood R&D

The third avenue for individuals to be involved in the innovation process was to have researchers using their skills and reputations as freelance R&D resumes designed to land them big contracts. Scientists known for winning multiple open innovation challenges become "celebrities" in high demand.[40] Rather than commit to single companies, these stars make themselves available to companies on a temporary basis at high salaries. This increases the risk for companies that are willing to pay their fees.

Globalization and consumer demand also continue to increase the risk of bringing new products to market, however, meaning companies must find ways to expand creativity while reducing risk. Looking at business models of other high risk, high creativity industries with well-compensated stars, they find and adopt the structure of Hollywood movie studios.[41] Corporate R&D managers become producers who are given funds to hire the celebrity scientist "directors" and, with their input, cast the innovation project.

Freelance researchers are hired based on past success (e.g. their "box office" scores), fit with the project (e.g. comedy, drama, or action thriller actors), experience of the producer or scientist from previous projects, or industry awards (e.g. how many Oscars they have). Third-party talent exchanges, similar to Hollywood casting agencies, then spring up to help staff R&D projects.[42] These agencies help create the best mix for creativity and success, using the scientifically proven right ingredients of people that have worked

together before alongside researchers that are new to the rest of the cast. The once vertically integrated R&D group has exploded to have many service functions operating as separate companies, such as lab design and construction, simulation "special effects" houses, and talent agencies.

This Hollywood Model returns disproportionate success to some of the celebrity scientists, while many researchers "work for scale" and may need to take on other jobs to make ends meet while they wait for their "big break." In short, for every George Clooney celebrity scientist there are thousands of aspiring researchers working in simple labs in Silicon Valley, the Research Triangle, and Beijing. However, it also maximizes the speed and creativity of R&D projects while spreading the risk across many players.

Scenario System Architecture

IRI workshop participants examined how third order impacts of drivers and weak signals of change from the Futures Audit and Weak Signals reports would interact to influence each other. The following diagram served as the baseline for the construction of the above narrative.
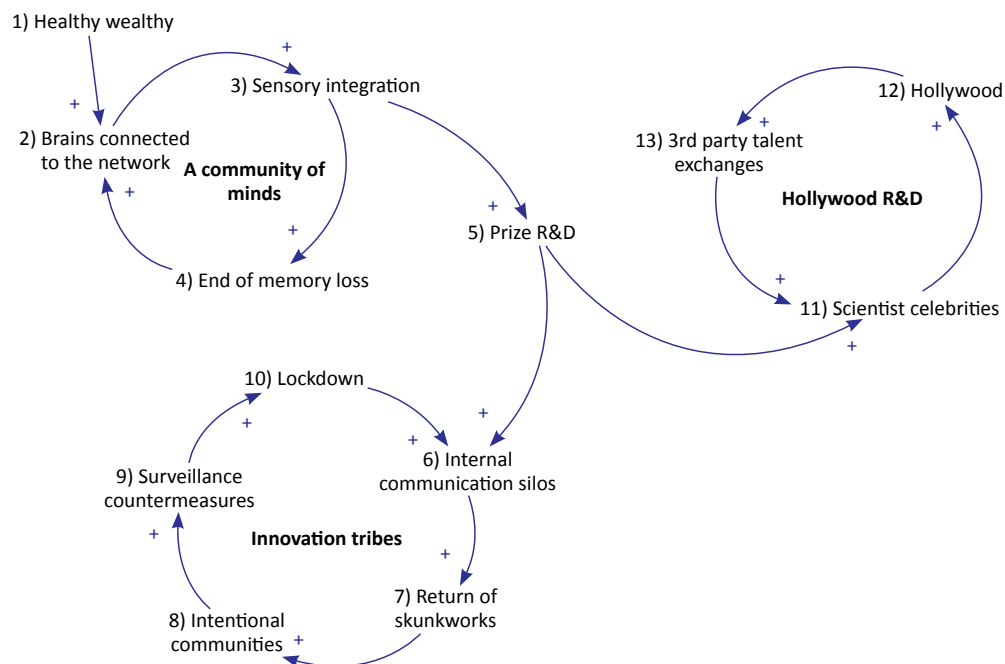
Scenario Analysis

The scenario suggests three alternative ways innovation will be pursued in the future. All of them are an expression of different approaches to trust and identity. In a community of minds, trust is developed by the nature of the network everyone connects to, and identity is subsumed in the network. Innovation tribes gain trust by intentionally choosing a small group of people who rely on each other for success

in work and in life. Their identity is first their tribe, then as individuals. In the Hollywood Model, trust is gained through contracts and personal connections. Identity is tied to industry success.

These approaches to trust and value influence leadership and decision-making. In a community of minds, network intentionality trumps individual will, as people become nodes in a larger consciousness. For innovation tribes, decisions are often highly democratic and power is derived from elder status and the ability to persuade. In the Hollywood Model, power is decentralized to independent project manager "producers" so that the overall company can defray risk by running multiple projects that are not encumbered by the slow speed of decision-making from company executives. Successful innovation can be found in all three paths, but the scenario poses questions for R&D professionals on how they will react to challenges of trust and identity in the future.

Implications for R&D Management

Discussion during the development of this scenario focused on four areas of impact: Project Management, Portfolio Management, Value Proposition of Research (to companies and society), and Talent Management.

- **Project Management Implications**
  Stage-gates do not disappear, but become automated and their number is reduced by using simulations to better map the project's progress. Managers concentrate on being more collaborative and integrated with the rest of the organization and community rather than day-to-day project management that is handled by intelligent software. Assembling and managing team capabilities is also critical.

- **Portfolio Management Implications**
  The need to articulate what the company is looking for is critical in managing the portfolio. Requirements management is needed to create architectures that are more responsive across the portfolio. Managers will be handling many very different types of projects, from highly open crowdsourced models to tightly controlled internal programs with trade secrets. Managing the flow of information differently for each project to maximize creativity and protect trade secrets will be a key source of advantage.

- **Value Proposition of Research Implications**
  R&D will deliver value to companies by identifying future customer needs and picking the best research model to solve for those needs. Companies will value speed-to-market and strong evidence of demand, so the use of prototypes and fast feedback will mean projects get taken all the way to market before being handed over to marketing and sales.

- **Talent Management Implications**
  Managers will need to spend a lot of time influencing and cultivating the community of talent available so that teams can be assembled from the freelance workforce quickly. Researchers will need to be lifelong learners, continually engaging in competency-based credentialing to be desirable for new projects. Speed and accuracy of assembling the right team will also mean using simulation. As software moves into talent and project management, researchers will need to develop an ability to manage or be managed by AIs or expert systems. This will include the need to maximize human creativity in a world of automation.

Overall, managers will need to have a facility for managing software and people. Simulation and AI expert systems will free up managers from day-to-day project oversight, but time saved will be taken up by the requirement of cultivating a network of external talent that can be assembled for projects as they are commissioned.

Scenario 4: Everything's In Beta

"The collapse of the complex global manufacturing ecosystem leads to a bifurcated economy underpinned by local manufacturing. At the low end there is massive churn of new products that are introduced as beta products with little market research. On the other stand premium products that are socially reputable and deploy R&D resources towards tackling the big challenges of the 21st century."

— Excerpt from the IRI2038 Futures Study Scenarios Report

The fourth scenario to emerge from our working groups explored questions of intellectual property changes and a general movement towards sustainability in business. The trends and weak signals analyzed from the Futures Audit and Environmental Scan that were used to form the baseline of this narrative are:

- Value Chain Open Innovation;
- Challenges to IP Protection;
- A social and business ecosystem trend toward sustainability;
- The rise of a Zero Waste Society;
- A trend that sees multiple 3D Pop-Up Labs emerging;
- An ascendant Era of Women; and,
- New Corporate Entities altering the business landscape.

Beginning with future impacts derived from these trends and signals, this inductive scenario developed as participants identified interactions and simple systems comprising them. Workshop participants felt that as R&D projects grow in complexity, organizations will come to engage their entire value chain of suppliers, retailers, and customers to deliver new value. This open model, however, will put strain on the ability of organizations to protect their intellectual property. This value chain innovation will be occurring within an increasing societal demand, and business requirement, for environmentally sustainable manufacturing and end-of-life reuse of materials.

Buyer Beware

By the 2020s, e-Commerce, just-in-time production, and predictive algorithms are expected by this workshop's participants to tie together the world's commerce. Reverse logistics will return products at end-of-life to be reused, and supply chains will become highly tuned and complex symbiotic ecosystems of supply, production, consumption, and recycling. But natural disasters, political revolutions, and economic disruptions reveal that this global system is very sensitive to disruption and not very resilient. Whole economies die off as they are overwhelmed by complexity and change.[43]

By 2038, new, smaller, and simpler economies are assumed to rise and replace the previous global system. In this new world, predictive data and long, thoughtful product development has been replaced by speed-to-market. Companies flood the market with beta products and wait to see which may take off with consumers.[44] Because consumers are basically buying prototypes, companies are protected from product liability claims, and even the best brands resort to rushing products out as fast as possible.[45] Consumers expect much lower prices since products are developed in the absence of any patent or licensing costs, and consumers buy them agreeing to be "beta testers."[46]

Hardware as a Service

In this relentless churn of new products, participants saw that providing a platform for consumers to aggregate products or services together—such as the smart phones of the past—is the best form of locking in customers and building a sustainable competitive advantage.[47] Physical products are embedded with the ability to connect to networks, play with other products, and continually upgrade their abilities. Because these products are produced so quickly, a secondary documentation market springs up that crowdsources knowledge from designers, consumers, and company representatives to deliver product specifications, FAQs, hacks, and easter eggs.[48]

Social Innovation for Big Problems

The collapse of the manufacturing ecosystem anticipated during the construction of this narrative led many participants to see a new product creation and distribution model emerge that depended on local suppliers and smaller plants closer to customers that can customize products.[49] While these plants might spur the high consumption churn of "buyer beware" and "hardware as a service" models, they also enable society to start creating long-term innovation projects to solve the world's biggest problems, one community at a time.

It begins as more intentional communities form within existing cities or in formerly rural areas. The 21st century's reliance on relationships, nuanced communication, and collaboration elevates a much higher percentage of women into leadership roles in business and politics. To manage work/life balance, families of successful women choose to live in small, high trust communities that share childcare and other family services.[50]

These communities tend to value the social good companies do, not just their products or profit margins.[51] As a result, more companies might invest in R&D projects to benefit these intentional communities that are lucrative markets for premium products. They would begin by looking inside their companies and applying innovation knowledge and R&D resources to improve their own internal processes. This helps them meet the stringent criteria of intentional communities for environmental footprint and ethical and equitable salary and benefits. The PR victories these actions produce lead companies to put more money and R&D time toward solving some of the major challenges of the time, including energy, sea level rise, carbon dioxide levels, and access to affordable healthcare.[52] Investment in fundamental science research, under this scenario, would dramatically increase.

But many social benefit efforts by companies initially lead to unintended consequences and negative outcomes. Geo-engineering projects backfire and increase warming or reduce capacities of biomes to support endangered species. R&D groups leverage the huge computing and simulation power at their disposal to develop a better understanding of the underlying natural and human systems they are trying to influence. The language and toolset of systems thinking, such as leverage points, reinforcing loops, and system dynamics modeling, grows to become a significant part of R&D processes.[53] The best R&D professionals and companies become known for their positive impact on society, and are rewarded with tangible and intangible rewards through social media.[54] These reputation economies also help mitigate the worst transgressions of the buyer beware churn.

Much of the innovation happening in 2038 is completely transparent in this scenario thanks to both the lack of IP protections and the high amount of innovation occurring for the public good. Services spring up that sift through all of these innovations, linking together companies that have complementary capabilities from very different parts of the value chain or geographies. These linkages often turn into joint ventures that yield breakthrough and transformative innovation.[55]

Scenario System Architecture

IRI workshop participants examined how third order impacts of drivers and weak signals of change from the Futures Audit and Weak Signals reports would interact to influence each other. The following diagram served as the baseline for the construction of the above narrative.
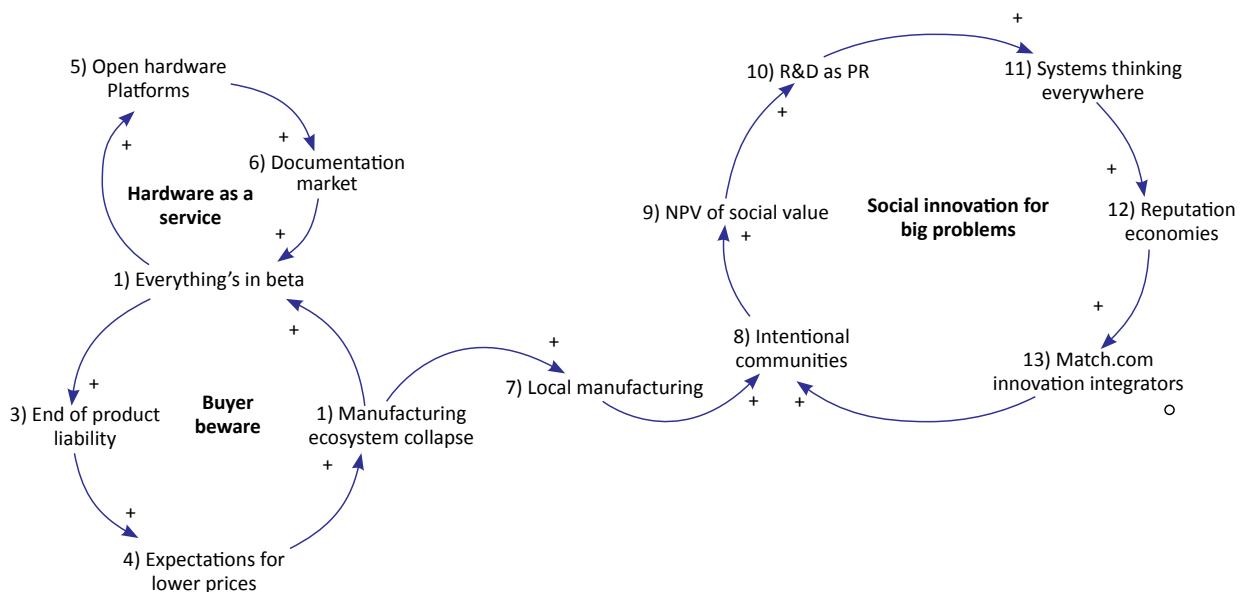
Scenario Analysis

A collapse of the complex global manufacturing ecosystem produces a bifurcated new economic world. On the low end, an enormous amount of innovation energy is wasted as most new products are thrown into the world as fast as possible. But another economic model forms that enables R&D professionals to have the funding, time, and commitment from their companies to do fundamental research

and participate in solving the big challenges of the century. The glue that holds both of these worlds together is the high adoption of local manufacturing, enabled by 3D printing advances.

Values in this scenario are participatory consumption and the conflict between quality and quantity. Consumers and innovators work together to make sense of the chaotic world of new products, and companies and communities come together to make the world a better place. A market of beta products that link together and upgrade themselves exists for inexpensive items, technologies that change very quickly, and the insatiable first adopters. At the same time, curated transformational inventions exist for the premium markets.

Implications for R&D Management

Discussion during the development of this scenario focused on four areas of impact: Project Management, Portfolio Management, Value Proposition of Research (to companies and society), and Talent Management.

- **Project Management Implications**
  The details of project management become fully automated, with humans focused on vision and big decisions. Project managers are replaced by an "artistic model" in which "rock stars" grasp consumer or customer needs and lead everyone else. For rapid product development the key will be sourcing from the cloud. Solving big social problems for intentional communities will require embedding resources within those communities.

- **Portfolio Management Implications**
  This scenario suggests the end of the closed R&D model, with greater collaboration for human good catalyzed by the demise of intellectual property. But closed R&D could be reinvigorated if identifying unarticulated consumer needs becomes the dominant basis of competitive advantage. Portfolio management will be less structured, more agile, smaller in scale, and less asset-based—"management by beta testing." Managing the portfolio will become complex as they become part of a larger portfolio of networks, communities, and relationships.

- **Value Proposition of Research Implications**
  Value for the intentional communities is built by solving social problems. For the rapid product development part of the scenario, value is created by managing data, by working faster, and by reducing costs. For organizations, value will be based on effective knowledge management and building an ecosystem of partner relationships. Both organizations and individuals will need to build and track their reputations.

- **Talent Management Implications**
  Two different types of projects populate this future, and each will strain the ability of managers to provide equitable opportunities for researchers: big, compelling work to address major social problems; and, short, fast, repetitive work churning out an endless stream of new products. In this bifurcated world, different types of talent and different recruitment strategies will be required. Managing and developing careers will be much more difficult, and career mobility between the rapid product development and intentional communities may be very limited.

This scenario implies that two very different management styles and skills will be needed. Once managers build skill and experience in one model it looks unlikely that they would be transferrable to the other model. Managers in this scenario will need to choose early in their career if they want to work in an open, fast-paced but incremental model based on endless consumer demand, or in a more closed system of longer projects that tackle large societal issues.

Chapter 3: Crowdsourcing Support for the IRI2038 Research Findings—The Innovate2038 MOOG

As part of the IRI2038 project, IRI partnered with the Institute for the Future (IFTF) to offer a massively open online game (MOOG) to those interested in forecasting what the world of R&D management might be like in 2038. The purpose for creating and running this MOOG was two-fold. The first was to open the project up to contributions from people around the world that we would not normally expect to hear from; e.g., students, hackers, academics, and emerging leaders. Secondly, online games for positive intent (i.e. those designed to explore specific topics) are an increasingly popular tool and the project team wanted IRI's membership to experience one. The game was called Innovate2038 and was leveraged on IFTF's Foresights Engine. The game asked participants to write 140-character responses to one of two questions, or in response to other participants. The two questions asked were, "How can new research and innovation practices lead the way in 2038?" and, "What obstacles and roadblocks will hold research and innovation back?"

The results of Innovate2038 exceeded our expectations. More than 10,000 ideas from 543 participants from 53 countries were submitted, all in the span of a 36-hour game window on September 15-16, 2013. So what did the crowd think about the future of R&D management? After analysis of all 10,000 idea cards, seven themes became apparent, all of which supported the IRI2038 findings and analysis:

1. R&D as a Public Movement
2. R&D Process Changes
3. Adjusting Talent Management
4. Critical Skills Development
5. Emerging Tools
6. IP and Publishing Changes
7. Shifting Priorities for R&D

R&D as a Public Movement

According to Innovate2038 players, R&D must become an inclusive, public movement to answer the big challenges and to scale important opportunities of the next quarter-century. Players were unambiguous in their call for R&D to open up to diverse perspectives, ideas, and modes of contribution.

First and foremost, R&D needs to become inherently social. Players forecast coordinated communities of citizen researchers, shared virtual worlds that link simulations, and several models of problem-solving collectives ready to tackle challenges on-demand. The current success of crowdfunding was extended to future R&D efforts, with some players predicting this form of grassroots revenue as the largest source of research dollars in 2038. Players didn't miss the meta-connection to the Innovate2038 game itself as an example of crowdsourced invention, calling for more innovation contests and games to leverage creative play and inject fresh talent and ideas into existing institutions.

Players also imagined exciting new tools and interfaces to make R&D more accessible to more people, from opening corporate labs to citizen use, to Minecraft-inspired simulation software, or even the construction of a science amusement park that would double as a maker-space. Critical to opening research and innovation to greater participation is re-thinking how a larger public will contribute to ongoing projects and investigations. Many players presumed a future of micro-contributions in which larger groups of people contribute in smaller units of time, investment, ideas and feedback—much like the Innovate2038 game itself.

R&D Process Changes

The fundamental processes of R&D will be reinvented, according to Innovate2038 participants. Players' ideas ranged from high-impact tweaks to existing models to wild new possibilities. Many players took on the basic structures of organizational R&D to adapt for the future, imagining flat hierarchies, entirely virtual firms, self-assembling teams inspired by slime molds, and conveyor belt-inspired flows of collaboration from one expertise to the next. But players weren't in consensus: in one thread R&D groups within corporations become core to strategy and governance of the organization, while in another all corporate R&D is outsourced to other entities.

Players did coalesce around a need for faster realization of ideas, including multiple investigations per research question; rapid-approval, open source R&D funds; and, stronger connections between industry and academia. The relationship between R&D and governance was a hot topic in Innovate2038, with much conversation about innovating new forms of governance to facilitate faster innovation.

And for all of the more pragmatic discussions of reforming R&D processes, players did not ignore the far-reaching transformations of the coming decades. A larger cluster of players and ideas formed around the emerging technology of brain-machine interfaces and the subsequent potential for neural networks that directly connect the minds and thoughts of colleagues and collaborators.

Adjusting Talent Management

Recruiting talent and organizing teams for R&D in 2038 will be more fluid and inclusive. Players clearly see the rise of free-agent collaborators routinely brought onto projects to add a needed skill or domain expertise—and institutional policies and barriers have eased to support this constant stream of external talent. Teams in 2038 are inherently fluid, assembled to meet the demands of each project and disbanded.

Players eagerly invented new tools to find the right person for any job, including searchable talent management banks, talent exchanges, mining the online data trails of potential candidates, and quantified reputation scores from their work on past research gigs. Diversity of perspective and thinking will be critical to innovation in the future, according to players, who pointed to immigration policies and gender inequality as potential barriers to more inclusive and productive organizations.

Players had strong opinions on the future of R&D careers, speculating about threats from machine intelligence and a need for continuous retraining while imagining new opportunities for mid-career development and 'intrapreneur' programs to harness the livewire energy of startups within established companies.

Critical Skills Development

A new set of skills, practices, and limitations will emerge for researchers and innovators in a future dominated by abundant data and machine intelligence. The core of this discussion was an evolving relationship between human workers and the exponentially improving capabilities of software to support or execute every phase of the research process.

Some players maintained that people will still be best at sensing patterns and intuiting opportunities, even as they suggested we will augment our bodies and minds with technology to keep pace with our algorithmic colleagues and the complexity of 21st century challenges. Even seemingly human intuition will be enhanced through better scientific understanding of hunches and nudge tools to overcome cognitive bias.

A cluster of forecasts concerned the impact of digital distraction on innovation and creativity, and players prototyped several forms of tech-free space where people in 2038 could retreat to think deep thoughts. As R&D projects open up to greater participation by massively more people, players also identified a need for community management to organize contributions and motivate citizen researchers.

Emerging Tools

Advances in simulation, machine intelligence, and data analysis will offer scientists, researchers, designers, and other innovators extraordinary tools to make the future. Players were excited about big impacts of technology at every stage of R&D processes—from data-driven opportunity scouting and networked virtual labs for collaborative product design, to algorithmic project management and nested bots operating as a multilevel marketing arm.

Many players also re-imagined research collaboration facilitated through intuitive interfaces—gesture recognition, natural language search, automatic language translation, in-situ augmented reality training, and high bandwidth, low latency network connections for working seamlessly across locations.

But the opportunities offered by these tools come with significant risks, players warned. Several discussion threads concerned ceding too much control to runaway algorithms that become black boxes past limits of human understanding.

IP and Publishing Changes

Intellectual property and publishing models will evolve to enable R&D to grow into inclusive movements and meet critical challenges. Players foresee a complicated relationship between R&D processes that open up to include public research communities and crowdsourced ideas and current IP and patent systems that may have a difficult time adjusting to more fluid forms of collaboration.

Players focused on patent reform, creating adaptations like temporarily borrowable patents, 18-month time limits to put patents to use, and shifts from first-to-file to first-to-invent or even a no-patent, first-to-market system. Open R&D innovation banks were popular as a means to prevent inventions from being siloed without further development, including one idea for a microtransaction-based IP exchange between enterprising individuals and innovation networks.

Players also took on the contentious issue of research publishing, calling for a democratization of the academic-industrial publishing system to meet a changing world of innovation outside institutions. In a surprising thread, several players imagined a future of algorithmically authored papers peer-reviewed by other algorithms.

Shifting Priorities for R&D

R&D has the capacity to help humans avoid disaster. In between reimagining the how of R&D, players shared many ideas for what the critical priorities for R&D should be. Many of these challenges are inextricably connected: water, energy, resource consumption, and, most potentially disruptive, the changing climate of the planet.

Players described several water-related goals, including water treatment and purification, improved sewage systems, and new approaches to reducing consumption and improving efficiency. Power grids were the big focus of energy ideas, with one thread centered on crowdfunded and managed grids to make renewable energy sources a viable alternative. As gameplay heated up, players merged discussions around scarce resources, new materials, and a potential to shift away from consumption as a driver of the economy.

Many players saw climate change as a serious risk to an open pursuit of R&D, speculating that a degrading environment would force research and innovation to prioritize environmental adaptations for survival. Players saw emerging R&D potentials in aging and growing populations, as lifespans increase and birth rates decline in many countries around the world. For all the urgent opportunities players identified, they also imagined many risks to research and innovation heading toward 2038. From a carbon bubble burst to global pandemics to the impact of present-day debt, players foresee many potential scenarios that would force immediate reprioritizations of R&D efforts around the world.

Innovate2038's Clear Parallels to IRI2038

Innovate2038 game participants explored the future of R&D management, its risks, its roadblocks, and its opportunities, and offered a vision of the future strikingly similar to the vision our IRI2038 project team had constructed. The seven themes outlined above contain elements with clear parallels to the IRI2038 scenarios.

MOST FORECASTING POINTS	MOST FOLLOWED	MOST SUPER INTERESTING
Hathor — 131190	Hathor — 15	Hathor — 24
NullDeco — San Francisco, CA — 68346	Gardener — Silicon Valley — 11	Cypher — Atlanta, GA — 6
JimmyLP — Orlando, FL — 43304	mackenziedickson — Vancouver — 7	Cosmic_Mitch — Washington, DC — 6
Gardener — Silicon Valley — 37382	Bagelx — Right next to Marci — 7	NullDeco — San Francisco, CA — 6
plan_then — Oakland — 23406	acclouse — Houston — 6	CrowdOfIdeas — Portland, Oregon — 6
jkimhan — California — 22332	jogger1031 — Texas, USA — 5	Gardener — Silicon Valley — 5
SaschaGoto — San Francisco — 16802	NicoleTrapp — san antonio TX — 5	jkimhan — California — 5
mackenziedickson — Vancouver — 14770	ahines — houston, tx — 5	RDRoadWarrior — Detroit, MI — 5

Chapter 4: Backcasting Results

Step into the year 2038 under the <u>Africa Leapfrogs Developed Markets scenario</u> and describe what you are seeing and experiencing. What would be the characteristics of successful research and technology management in this future? Now, what would need to have happened just prior to 2038 to make that vision a reality?

Backcasting sessions work because they start with a solution, no matter how unlikely, and work backward. Instead of beginning with today and working forwards, we start in the target future and step back in short stages to the present. The results of these two methods will differ from one another drastically because linear models that start from today tend to base their assumptions on what is possible today while backcasting incorporates the availability of future capabilities.

A typical backcasting workshop will consist of approximately 6-12 people; the group should be small enough that people cannot get away with staying quiet, but large enough that the responses generated are diverse. The length of a backcasting session varies. They can run anywhere from one hour to several days depending on the objective of the project. The results of the IRI2038 backcasting sessions are products of small groups exploring each scenario for 90 minutes.

IRI's backcasting sessions were conducted globally. Satellite participants in Brussels, the UK, and India each took the scenarios and explored them in a backcasting session of their own and then reported their findings in PowerPoint or video format to meeting participants in the United States. The results of all of the backcasting sessions were then taken in aggregate and recapped by the IRI2038 project leadership during the meeting. Those aggregate results are explored below.

Africa Leapfrogs Developed Markets

Under a scenario driven by greatly diminishing access to natural resources, and in a world where the R&D talent pool has been equalized by easily accessible MOOCs, Africa has risen to global prominence as its lack of legacy power grids and infrastructure allows it to more easily adapt to the new order of economic power. The emergence of a flexible, ad hoc, 3D printing market also grants organizations the ability to shift their manufacturing needs, giving strength to local producers with better access to natural resources. If we were to step into this future, what would we expect to see? When participants of IRI2038's backcasting sessions were asked this question, these are the key implications they derived:

- **Almost Free, World Class Education:** Backcasting participants felt that this would need to be achieved very early on, sometime around the early 2020s or late 2010s, in order for this scenario to work. They also felt that this is a precursor to much of the other changes expected in this scenario; without such educational access much of the other changes become less likely. The early development of universal access to Wi-Fi is also critical to support accessibility.
- **Virtual Enterprises:** Micro-manufacturing paired with virtual avatars allows organizations to engage workers anywhere in the world. Cultural issues will need to be resolved early on for this to work and universal access to Wi-Fi is important. Participants expect the government to begin investing large sums in public R&D since infrastructure will play an increasingly significant role in this scenario's emergence.
- **Nimble Talent Sourcing:** As MOOCs level the talent playing field globally, it is assumed that talent sourcing agencies will have to become much better, and faster, at recognizing talent and pairing that talent with relevant projects; a type of Match.com for recruitment agencies, perhaps overseen by advanced simulation AI.
- **Islands of Production:** Given the flexible, ad hoc nature of manufacturing and production, isolated areas with access to specific resources (e.g. minerals, oils, water) will begin to specialize in the production of goods tailored for those resources. Multiple Silicon Valleys will form around local competencies in Africa. The construction of safe, rapid transit networks across Africa are therefore critical for success, meaning African nations will need to form an effective union to collaborate on infrastructure development or attract the right outside investors to do it for them.

Participants who entered the year 2038 under this scenario expect that universal access to Wi-Fi and the growth of infrastructure collaboration around the year 2020 will have paved the way for virtual enterprising. Horizontal integration will occur with smaller organizations based near rich natural resources across Africa, where specialized innovation clusters have emerged thanks to near-free access to great education. Employment agencies are much better at recognizing talent and sourcing that talent to relevant agencies. The submission of project managers to advanced AI software is a hallmark of this scenario as human talents shift to the maintenance of the simulation devices performing the difficult work of monitoring the global network of talent pools instead of performing that work themselves.

What to watch for
- The emergence of low cost, easily accessible education
- Universal access to Wi-Fi
- Collaboration on infrastructure development across entire continents
- Emergence of specialized research clusters around natural resources
- Advances in talent sourcing
- Rise of freelance R&D workers
- Pop-up 3D printing companies scattered globally
- Virtual employment becoming standard

Death of Distance vs. Mega-Cities

Assuming cities emerge as the key actors on the political stage, and assuming that their control over production and acquisition of goods and services depends on constant monitoring of personal data, what would we expect to be the norm in everyday life under such a scenario? The backcasting participants who stepped into this scenario came back with these key implications for such a scenario to be true:

- **Big Data Analysis is Vital:** R&D organizations come to rely on the ability of advanced AI to process enormous stores of data while human researchers focus on analysis. This must be accomplished early on to allow this scenario to emerge. Without a better data analysis capability, much of the implications of this scenario will struggle to become reality.
- **R&D Talent Pool Tipping Point:** Sometime in the next 10-15 years, a tipping point in R&D employment will be reached where long-term, full-time work ceases to be standard and most R&D workers become freelance agents operating within a global, project-based talent pool, supported by virtual access to anywhere in the world with zero to no relocation expense.
- **Faster, More Open R&D:** R&D organizations become much more open, crowdsourcing ideas and analysis to better anticipate needs. The result is innovation moving at breakneck speeds, synced with advanced simulation software that has largely overtaken the job of the traditional project and talent managers of today.
- **R&D Organizations Align with Cities:** As cities begin to decide the allocation of resources in their areas using Big Data AI, organizations will work hard to get ahead of those decisions by performing the same customer and data analysis that cities perform in order to better service the needs of specific cities, thereby winning the contract to provide their products or services and also supporting the emergence of mega-city control over political decisions.
- **Long- and Short-Term R&D Successfully Addressed:** Long-term, infrastructure and resource R&D is solved on a per-mega-city basis and then shared across the network of mega-cities, allowing long-term, large-scale projects to be conducted at much faster speeds. Open innovation and advanced simulation AI also allows short-term, consumer-based R&D to move at lightning speed.

This scenario portrays a future world where cities make the big decisions instead of federal governments. The alignment of organizations with mega-cities gives impetus to the city's push for autonomy. The faster, more successful pace of long- and short-term R&D also means life in the mega-city overall is improved. However, the perceived invasiveness of the data collection is countered by a tipping point in talent sourcing where virtual work becomes standard and people no longer have to live under the direction of a mega-city, creating a healthy societal balance.

What to watch for
- **Advances in Big Data analytics and AI**
- **Freelance, virtual R&D work becoming standard**
- **Cities becoming more powerful than federal governments and wresting autonomy from them**
- **Companies supporting city autonomy by tailoring their goods and services to the city's needs**
- **Large-scale collaboration on infrastructure development and more efficient resource use**

Three Roads to Innovation

What would we expect to see in a world where three separate paths to innovation emerge thanks largely to the growth of virtual work and prize driven motivation? In path one, those with the desire and ability sync up their brains to a central network to produce a cohesive unit with the combined knowledge of its members. This is made possible by advances in nano- and bio-technology. Those wishing to avoid the intrusiveness and lack of individuality from such a network of minds go off-grid and form intentional communities, walled off from the outside world. In path three, R&D superstars emerge quickly from their ability to conceptualize challenges more effectively and earn a high rank among talent sourcing agencies. A Hollywood model of R&D emerges where short-term, ad hoc teams are brought together for specific projects, potentially including an R&D superstar.

During the backcasting workshops on this scenario, participants derived the following key implications to watch for that would signal a higher probability of this scenario becoming reality:

- **Employer of Choice:** Early on, organizations would need to realize what it takes to become an employer for which everyone wants to work. Organizational culture innovations help create positive work environments and this is made possible by brain mapping individuals to better mold an organization to the personality, mood, temperament, and outlook of employees. Most organizations begin to identify R&D superstars and return to them frequently as part of their R&D team, creating a reputation ranking system for those in a talent pool.
- **Market Intimacy:** The brain mapping process used to create amazing organizational environments also allows companies to better understand their customers' needs. The data collected from this process makes organizations much more closely aligned with the market and better able to adapt.
- **Effective Knowledge Management:** Organizations making use of the linked brain network will develop effective barriers within the network to mask trade secrets from temporary employees while still granting tremendous access to computing power through knowledge management software and AI. Brain to cloud software can harvest know-how without infringing on trade secrets.
- **Fast, Flexible Project Management:** Participants did not expect the AI software that could automatically manage projects to emerge until around 2028, but the preconditions to put this AI to use will have already been in place; namely, the cultural changes necessary to make an organization attractive, agile, and supportive, and the brain mapping software to gain access to enough data to anticipate market needs.
- **Attracting Top Talent is Key to Success:** Most organizations will realize that they need a better pay scale and more inventive reward mechanisms to attract the top R&D superstars. A New York Yankees-type pay scale will emerge, granting sizable bonuses to high performers over temporary contracts. This remuneration structure will pave the way for the Hollywood Model of project management to become reality.

The key changes participants saw emerging to make this scenario a reality were largely organizational in nature. Companies are recognizing that the R&D talent pool's needs, desires, and attitudes are changing. To accommodate this change, organizations acting ahead of the curve begin to find ways of adjusting their culture to be more flexible and attractive to the emerging workforce. The skills needed to do this also help those organizations better anticipate the market, allowing them to leap ahead of their competitors and spread their style of culture change more rapidly across other organizations. The speed and flexibility of the new, dominant, organizational culture paves the way for faster and better project management.

What to watch for

- Companies developing brain mapping software to better understand employee and customer needs
- Advances in Big Data analytics and AI
- Advances in nano- and bio-technology which make the brain mapping more accurate and effective
- Companies marketing themselves for their R&D innovativeness
- A restructuring of employment contracts, bonuses, and pay scales to be in line with Hollywood or professional sports
- A conversation about privacy gaining momentum, leading some to wall themselves off inside intentional communities
- The emergence of fast, flexible, 24/7 project management software and AI

Everything's in Beta

A bifurcated global economy with small-scale 3D printing manufacturers churning out a multitude of new products on one end, and a large-scale, global R&D network working on solutions to the big challenges of the twenty-first century on the other. What does this world look like? Where do people fit in? Are they small-scale producers, creating new prototypes at a rapid rate? Maybe they are supporting this network by working in the service hardware companies or technical documentation consultancies. Or, are they in a large, established R&D company trying to solve the challenges of interstellar travel? How do we get there from here? Our backcasting session participants came up with these key implications of this scenario, anticipating how exactly such a future might emerge:

- **High Rate of Churn in NPD:** New product development (NPD) becomes a competition driven by a "first-to-market wins" mentality, where quality products stand out and gain the producer a good reputation while low quality products are killed quickly. Barriers to speed, like Stage-Gate® processes, are removed and action-oriented workers who are flexible are given a higher value than deep thinkers who look for stability/security.
- **Social Investment:** To stand out in a highly commoditized world, companies begin looking at how their products and services can support a social cause. R&D talent also begins looking to make their career less about producing products and more about helping humanity and/or the environment. A shift towards sustainability thinking drives people and organizations alike to look at the bigger picture.

The key implications of this scenario are a shift in how we produce things and how we let those things define the value of the world around us. Speed-to-market begins to define company value, not the number or quality of patents under lock and key. Patent filing even becomes dangerous as it makes public the designs that allow your trade secrets to work. However, as the high rate of churn in NPD gains momentum, society witnesses highly wasteful practices become the norm. Those companies able to make quality products with less waste gain better reputations because they have a better environmental/social impact. This leaks over into the workforce as individuals begin to seek jobs in companies with high social reputations to add non-product-based value to their professional lives.

What to watch for

- A shift to sustainability thinking in all things
- The elimination of barriers to speed in NPD
- Weakened IP laws nationally and internationally
- Companies foregoing IP filing in favor of speed-to-market
- Freelance, virtual R&D work becoming standard
- Pay scales and bonuses being restructured to offer social value to workers
- Pop-up 3D printing manufactories globally
- The emergence of fast, flexible, 24/7 project management software and AI

SECTION 2:
IRI2038 Research Process

Chapter 1: Discovery Phase

We all create mental models of the future. Each one of us carries this model with us throughout our lives, constantly updating it with information which may affect our own long-term future. Taken in aggregate, the views of veteran professionals within the same field can represent that field's broad mental model of the future. The process of gathering these mental models involves interviewing such professionals in what is known as a Futures Audit. This is step one of Phase One of the IRI2038 Futures Study.

To strengthen the Futures Audit, a retrospective is worth conducting. This report looks backward the same distance as the project is looking forward; for IRI2038 this is 25 years. The retrospective analyzes the key themes and trends explored at past IRI meetings, Research-Technology Management (RTM) journal articles, and Research-on-Research (ROR) working groups to see if the global drivers of change identified in the Futures Audit align with the changes seen emerging within these three archives.

The Futures Audit and retrospective identify global drivers of change that are agreed upon by professionals, as well as a select sample of technology futurists. The resulting report cannot stand alone, however, as it serves as our largely unchanging baseline map of the future.

Mental models of the future are rarely updated. While they are instructive in surfacing large, continuous meta-trends, such maps are easily disrupted by unforeseen changes to the landscape. To explore how the Futures Audit's global drivers of change may shift, a Weak Signals Environmental Scan then identifies areas outside the consensus mental model. These trends are not well known or acknowledged within the field, but have the potential to create significant change in the future. Taken in tandem, the Futures Audit, retrospective, and Environmental Scan allow individuals to discuss futures that account for expected major changes, as well as a variety of potential baseline shifts. These data collection methods are explored below along with IRI2038's findings in each.

The Futures Audit

The Futures Audit attempts to map the current mental model of the future that exists among research and technology management professionals and futurists. IRI2038's Futures Audit used interviews with 38 leaders across geographies and industries to discover the major trends impacting the field in the past, present, and what they believed will affect the future. While this was not a statistically representative sample, the shared beliefs about the core drivers of the future do point to an existing mental model of the future that is operant among research and technology management professionals.

While past IRI conferences and IRI's journal, *RTM*, have popularized several of these drivers—open innovation, for example—they were also present among the responses of non-IRI members interviewed.

If indeed the Futures Audit captured the current mental model of the future among R&D leaders, then nothing from this report should be a surprise. Drivers and trends mentioned should reaffirm predominantly held beliefs about the future among technology and research practitioners. As discussed above, it is important that the Audit is not the sole tool used for forecasting possible futures, and should be read alongside the Weak Signals report, which provides emerging trends that will shift the Audit's baseline view of the future along potential alternative paths. This comparison and analysis will be explored further in Phase Two (Extrapolation) of this project.

Methodology

The Audit interviews had four main sections. The first established the prior experience of the interviewee and current role in the organization. The second section asked the interviewees to look back to identify the major changes in research and technology management over the course of their careers. These questions open up the participants to the realization that significant change can occur and allow them to be more open to speculating about future changes. The third section dealt with changes the interviewees were currently seeing in the field. The final section used a number of different approaches to unearth their existing views on the future, including asking about what would surprise them, and to offer a vision of working in research and technology management in 2038. Asking about surprises highlighted held convictions about the future that were previously tacit; asking for a vision utilized the more generative than analytical brain activities.

The interviews were transcribed and coded to find trends impacting the past, present, and future of research and technology management. The 38 participants identified 84 trends. This report discusses the top 22 trends in the research and technology management field mentioned by the interviewees:

- Six from the past 25 years that created the present conditions;
- Six that are currently shaping it; and,
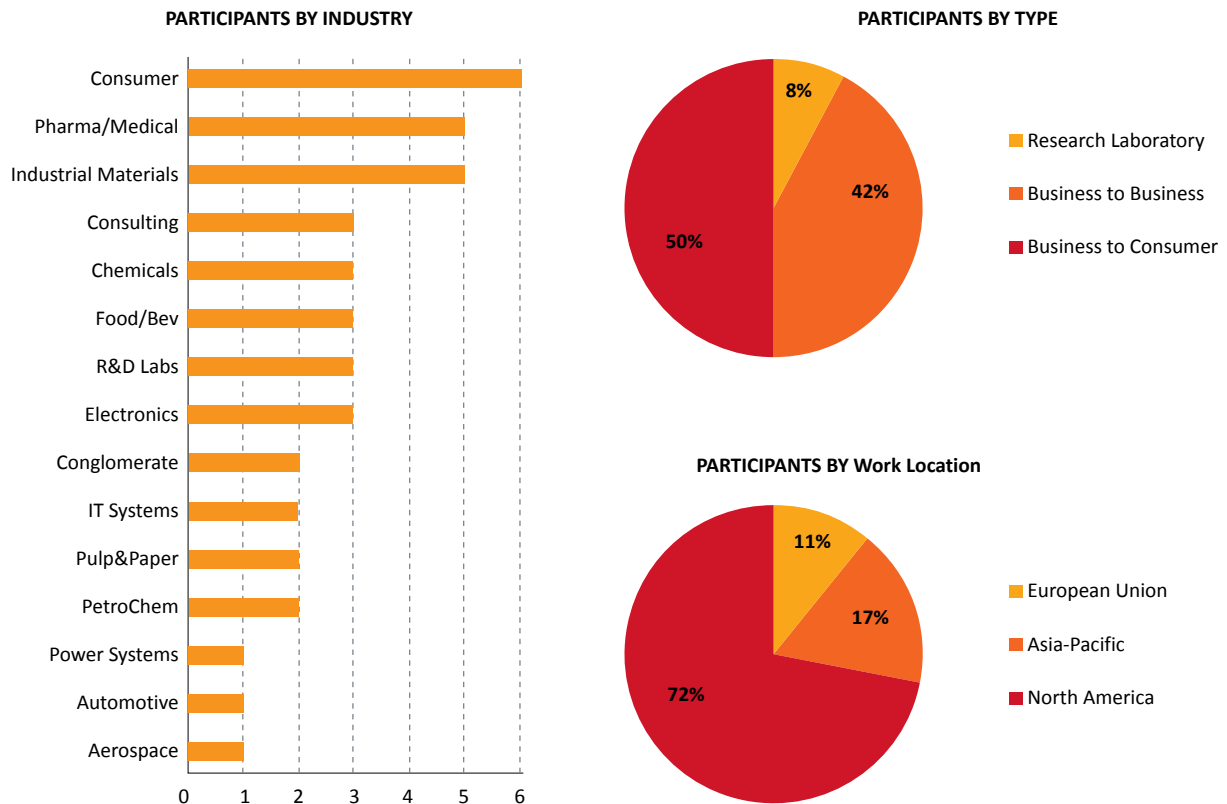- 10 that are expected to create change in the future.

These 22 trends are grouped by time (past, present, future) and by categories of change found in the Verge Ethnographic Futures Framework, developed by futurists Richard Lum and Michele Bowman.

Verge uses the different ways humans interact with their cultural touch points as an organizing framework. It is being used for this project for several reasons. First, it portrays trends not as abstract ideas but actual changes in human behavior. Second, these changes in behavior can more closely map to impacts on the sociology of research and technology management, not just the technology employed. In this way, Verge places softer social change on a level playing field with the powerful technologies impacting how research is done and how people are managed. This report is structured according to these Verge touch points:

- **Create:** How we invent and build products, services experiences, and knowledge;
- **Consume:** How we acquire, use and destroy the things we create;
- **Connect:** How we communicate with people, places, and things;
- **Relate:** How we affiliate with people, organizations, and social structure; and,
- **Define:** How we explain the world around us through concepts, ideas, and paradigms.

Participants

Futures Audit participants came from a diverse background of industries, regions, and experiences. The IRI2038 team used a matrix to ensure a wide range of leaders participated in the interviews, including non-IRI member companies and leaders.

PARTICIPANTS BY INDUSTRY

Industry	Count
Consumer	6
Pharma/Medical	5
Industrial Materials	5
Consulting	3
Chemicals	3
Food/Bev	3
R&D Labs	3
Electronics	3
Conglomerate	2
IT Systems	2
Pulp&Paper	2
PetroChem	2
Power Systems	1
Automotive	1
Aerospace	1

PARTICIPANTS BY TYPE

- Research Laboratory: 8%
- Business to Business: 42%
- Business to Consumer: 50%

PARTICIPANTS BY Work Location

- European Union: 11%
- Asia-Pacific: 17%
- North America: 72%

Results

Of the 84 distinct trends identified, some, such as the rise of computation or the access to knowledge embodied by the Internet, were global drivers of change far beyond the world of research and technology management. Others, such as the globalization of R&D or a strong connection of R&D to business strategy, are very specific to the field. Both types of trends and emerging issues are represented in the Futures Audit, since both types have significant bearing on the future of the field. Twenty-two trends were most frequently mentioned and are presented in the order mentioned (i.e. past, present, future).

Past Trends

The six trends mentioned most that have shaped the last 25 years of research and technology management are strong drivers that are affecting change now and will continue to impact the future of the field.

They include (with Verge categorization included in parentheses):

The Power of Computation (Create).

Interviewees began their reflections of the past 25 years talking about the incredible impact of Moore's Law and the power of computation on research and technology management. The exponential increase in the power of computation per dollar allowed the migration of computing from mainframes to desktops to cell phones over the last 25 years. This accessibility to computing changed the workflow of research, allowing researchers to do more work on local machines, not just data analysis itself but more of the visualization of the results.

Access to Knowledge (Connect).

An immediate corollary with the advance of powerful computation in the hands of the researcher and manager was the access to knowledge it enabled. Internally, all of a company's generated information became downloadable and searchable. Knowledge management moved from the corporate librarian to information technology departments, then to client-based software on laptops. While this migration increased the speed and effectiveness of researchers, it was the Internet that exploded the access to knowledge. Suddenly researchers could search all studies on a particular subject from all over the world, from their desktop. Interviewees cited the Internet's ability to leverage a single researcher's power through information and expected this leverage to continue to change the practice of research and technology management.

Globalization of R&D (Relate).

The combination of distributed computation and Internet connectivity allowed research to be done much closer to the local markets for which products were intended. Companies planted R&D centers in emerging markets as these regions grew into major strategic growth areas for mature market companies. Additionally, these R&D centers enabled companies to take advantage of the local scientific and engineering workforce, which grew significantly over the last 25 years in comparison with mature markets. As the emerging markets grew in size, local companies began performing a large amount of research, joining the broader research and technology management community. Interviewees were strongly in favor of moving research closer to customers, but many suggested this driver has increased the ability of local companies in emerging markets to compete.

Open Innovation (Relate).

Competencies built by companies to communicate and manage research projects among their campuses also created the ability to do the same thing with other partners beyond the company walls. Early examples of open innovation were restricted to specific projects with university or government labs, and then expanded to alliances or joint ventures with close partners. Later the skills of managing research beyond corporate boundaries expanded to a much broader definition as companies accelerated innovation that met customer demands by including consumers and the entire supply chain ecosystem in ideation. Participants were in favor of working and managing in an open innovation environment, but many mentioned the need for researchers to be coached or trained in skills necessary to work with customers and partners in identifying new product needs.

Increased Regulation (Define).

Advances in sensing and the globalization of operations have created a thicket of regulations for new products. The ability for governments to measure ingredients, outputs, and environmental and human impacts of substances and products has created an intimidating environment for companies to release new products. As one participant in the study suggested, "what can be measured, can be regulated." Additionally, the globalization of the marketplace and the democratization of consumers around the world have created a maze of special interest-led regulations. The result has been a more conservative approach to research and technology management, as the value of an innovation must be measured against the cost of bringing new products to market. Most participants expressed frustration in the limitations to research these regulations have caused, while some cited them as opportunities to design new products and services.

Shift from Fundamental to Applied Research (Define).

Almost all study participants mentioned the shift away from fundamental research over the past 25 years. While many suggested the move was positive and important for research and development to move closer to the operations of the business and its customers' needs, some lamented the loss of the transformational power of innovation driven by fundamental research. There were many reasons provided for the shift. The global competitive environment has reduced the ability of companies to devote resources to pure research that may not return money to the business for many years. Many interviewees also mentioned the perceived understanding that the fields available for breakthroughs with pure research were more limited, and that much of the major elements of science were known. The confusing global regulatory environment has increased the cost and timing of bringing fundamental research to market.

Present Trends

Participants frequently cited the following six trends as currently impacting the art and science of research and technology management. Many of these are a direct result of the drivers discussed under "Past Drivers" and also contribute to the 10 trends most mentioned impacting the future in the next section.

Shift of R&D toward Asia (Create).

Asian economies have exhibited consistently high growth rates even as mature markets remained flat or regressed during the last recession. This has prompted both mature markets and local companies to increase investment in R&D programs in Asia. Many interviewees mentioned their companies having established R&D centers in Asia staffed increasingly by local talent. This talent is easier to find since Asian governments have emphasized science and engineering education, making the skilled workforce more numerous in Asia. Study participants suggested this has resulted in a shift in the center of gravity for global R&D toward Asia. Mature markets will increasingly be served by research performed in Asia.

Increased Project Speed (Create).

Long-term drivers of computation and access to knowledge have dramatically increased the expectations of the business on the speed of R&D projects from inception to delivery. Companies now expect results in weeks or months rather than years, especially as the focus of R&D has moved from fundamental to applied research. Interviewees suggested the tools are there to support faster projects, but some lamented the lack of deeper thinking that could develop more breakthrough innovations.

Rising Global Standard of Living (Consume).

More and more consumers are able to spend discretionary income on products and services as a percent of total population than at any time in the world, and over a billion consumers will be added to this group in the coming decade. Solutions targeting these new middle class consumers will become a major focus for companies, and in turn their R&D departments. These cost effective solutions are challenging in non-traditional ways, in that solutions are often arrived at by removing ingredients, parts, or chemicals, emphasizing simplicity rather than luxury. Additionally, interviewees mentioned the challenge of thinking about the cost and availability of the commodities and energy necessary to build and deliver these products to new consumers.

Big Data (Connect).

The amount of data that companies can now access about their operations, customers, and market is remarkable. Sources include GPS, RFID, Internet behavior tracking, third party demographics data, sales data, warranty issues, and customer reviews. Interviewees discussed the significant efforts underway to standardize and make sense of all of the data to provide insights into new products and services. Research and technology managers must develop a competency in dealing with big data, knowing its value but also its limitations.

Shortage of Technical Workforce that is Hard to Retain (Relate).

Mature markets are educating fewer and fewer engineering and science students; even while the global demand for these skillsets grows. Emerging markets are producing large numbers of technically trained workers, but they may not have the business context necessary to be immediately useful. Interviewees stressed the need for mature markets to produce more technical workers, and the ability of companies to orient technical workers from emerging markets more quickly. Especially challenging for technology managers is retaining workers in different regions of the world that place different value on title, position, or pay. Companies must alter traditional career tracks or titles to ensure that valued workers can be retained.

Rigorous Connection of R&D to Business Strategy and Consumer Need (Define).

Most study participants cheered the tighter connection of R&D to business operations. Output from research was implemented more often and R&D departments were seen as a necessary part of business operations. This allowed many R&D groups to retain budgets and personnel more than expected during the last economic downturn. Many mentioned the cyclical nature of the focus for R&D, as companies shifted between highly tactical, incremental innovation, and a need for broader, transformational innovation. Several interviewees, however, asked the question of where truly breakthrough innovation would come from inside their companies, with most answering that question by suggesting it would come from outside start-ups almost exclusively.

Most of the above trends are very specific to research and technology management, with the exception of the global rise in standards of living, which interviewees suggest will cause resource scarcity and lead to a greater emphasis on sustainability in the future. The bulk of the interview topics, however, were on the future and 10 such trends were selected across the Verge categories that represent the diversity of elements participants identified as impacting the next 25 years the most.

Future Trends

It is difficult for humans to think ahead 25 years. As Ray Kurzweil has noted, humans forecast at a linear rate of change, while many types of change are exponential in nature. However, social change moves much more slowly, and can take an entire human generation to spread far enough to impact society. This study used a protocol that started by asking interviewees to look back a generation before looking forward. This sense of perspective was useful in helping participants comprehend the awesome speed of technological change affecting research. It also helped ground them in some of the timeless facts of managing people in a technology field. This combination of slow and fast change provided a venue for participants to offer a realistic forecast of what trends will impact the future, and how they might do so.

Simulation (Create).

Study participants discussed simulation in two ways. First, the current use of fast and increasingly inexpensive super-computing engines to simulate physical conditions, from turbulence to fundamental particles to biological systems, will expand in scope and frequency. Researchers will run thousands of experiments against these models in the time it used to take to perform one in the real world. This will dramatically speed up the time from idea to implementation, cutting the number of real world experiments and increasing their likelihood of success. Interviewees from pharmaceuticals, aviation, and chemical industries often mentioned this side of simulation. Second, consumer-facing companies looked to advances in simulation to better understand future consumer demands and marketplace shifts. Companies and researchers will increasingly use massive data sets and the application of stochastic and predictive modeling to find areas of innovation that will meet unseen current or perceived future consumer needs. Some suggested that no major business decisions would be made without first running stochastic risk models to identify potential impacts across an increasingly complex system.

For research and technology management, participants felt simulation would enhance the power of the individual researcher, but potentially add a layer of complexity to current business decisions. While some welcomed the rigor simulation might provide in implementing innovation, others argued this tool may become overused and take the place of the technology manager.

Robotics & Automation (Create).

As the cost of robotics drops and the capabilities increase, more and more lab work will become automated. Open source programming will allow faster and cheaper installation and re-tasking of robots as well. Interviewees see advances in robotics as a way for them to spend less time on tedious, repetitive tasks in the lab. Participants also see automation extending to the analysis of results. Expert systems or intelligent agents will sift through immense quantities of data to arrive at hypotheses for human review. Researchers will need to develop a facility for working in environments with very few humans, and with working with intelligent agents that do a significant amount of work and thinking for the researcher. Managers will need to add the care and feeding of robots and intelligent agents to their skillsets of managing humans. Done correctly, robotics and automation will maximize the effectiveness of the researcher, a potentially scarce future resource.

Sustainability (Create).

Whether or not interviewees felt climate change was driven by human activity, they believed that the needs of the environment will increasingly become a part of the economy. Consumers will drive the first wave of this change, demanding thoughtful

engineering and innovation to reduce environmental impacts for products they buy. Regulations will quickly follow to legislate the types of materials in products, seeking to maximize the recovery of non-renewable materials and mandate the percentage of renewable materials used. While some interviewees saw this as a potential threat that would increase the cost of innovation, others see sustainability as a welcome challenge for research and technology management to add significant value to companies. For researchers, an understanding of the entire value chain from origin of raw materials to re-use—"cradle-to-cradle" or C2C—will be necessary to innovate. Managers will need to spot opportunities created by consumer demand and government legislation while negotiating a confusing and contradictory global regulatory climate.

Biotech & Nanotech (Create).

Predictions of biotech and nanotech becoming the main driver of change in innovation have been around for over 20 years. And while both areas have grown into global industries, neither has yet to replace information technology as the prime engine of change in innovation. Looking ahead, however, many respondents felt that the next 25 years would be the era of bio and nano technologies. Biotechnology will finally reach the sweet spot of the S-curve of adoption. Participants cited advances in the automation of genetic analysis, the prevalence of inexpensive lab equipment, and the rising ability to deliver products, health outcomes, and even energy as markers that biotechnology will significantly impact the research landscape in the next 25 years. The idea of a nanotechnology future in which molecules are put together like Legos to create anything the researcher may desire was still not discussed by most participants even looking out 25 years. However, they did think that nanotechnology would become the basis for most new materials in the future, and that these new materials could enable transformational innovations.

For researchers, the maturation of bio and nano technologies was significant. Imagining biological assays in the millions, and 3D printers at the nano scale, participants suggested a new world of experimentation that exponentially increased the power and speed of the individual researcher to develop prototypes and instantiate ideas. For the technology manager, these technologies posed new complexities in navigating regulations about their application and use, as well as staffing challenges to find a skilled workforce in the future.

Resource Constraints (Consume).

Interviewees saw a significant commodities crunch ahead as the future population reaches 9 billion. Raw materials for products, food, and water will be harder to find and develop. Energy constraints will make it more difficult to deliver products globally to customers. Some participants felt that strategies of localization, where companies learn to use inputs for products found in local markets, and efficiency gains in taking water and unneeded materials out of products, would go a long way in meeting this demand. Others felt that resource constraints would open new sources of revenue for companies willing to invest to find solutions. A few forecasted a major downturn in the global economy due to severe food and water shortages, with human suffering in low income areas to be extreme. For researchers, resource constraints provide new challenges for innovation: process innovation to make products as efficiently as possible; ingredients and manufacturing innovation to use locally sourced raw materials; and, molecular manufacturing to solve the future food crises. Technology managers will be concerned with the percentage of research and engineering effort needed in each project to deliver product innovations to market that solve for resource constraints, and the need to find technically trained researchers to apply this discipline.

Virtual Workforce & Labs (Connect).

When participants were asked about a vision for a day in the future of research and technology management 25 years from now, almost all suggested a completely virtual work experience. The globalization of research and the sophistication and availability of video conferencing technology will mean that most researchers and managers will be interacting with each other through high definition screens in their own homes, often performing research in physical labs using robotic proxies. Some interviewees went further, suggesting researchers will meet and work together in entirely virtual lab environments, where simulations and data become physical objects to interact with. A fringe few suggested the Singularity, in which people and AIs would be connected in a merged virtual existence. But many interviewees felt that some face-to-face interactions would still be required. For them, no amount of realism introduced to video or holographic communications would replace physically working together. Most also felt that physical labs would still be needed, as simulation would not be able to totally replace real world experiments.

Researchers will be free to live where they wish, and manage work and home life much more seamlessly. Managers will continue to develop their skills at managing different cultures across multiple time zones. Instantaneous language translation, perceived as both possible and necessary in this future, will help, but the complexities of managing schedules of researchers who all work variably on different days or times of day will create a significant burden on managers.

Global War for Talent (Relate).

The need for the science and engineering workforce to have local contextual knowledge of their markets will be important for future success. However, outside of Asia there will be an increasing mismatch between areas that produce technical workers and those that need them. Mature markets will remain a major source of revenue for companies, yet will continue to produce fewer science and engineering graduates than are needed to keep pace with demand. Africa is projected to be the major engine of new growth for the world's economy, yet it will lag greatly in the education of scientists and engineers. Participants saw several impacts of this imbalance on research and technology management. As the shortage for technically trained workers grows, companies and countries will compete for talent anywhere they can find it. While initially a boon to researchers in the pay they can demand, it will result in being put to work on projects all over the world. They will need to quickly absorb the local culture and business context for the customers they are innovating for, and may need to access and interpret sophisticated ethnographic research. For technology managers, costs for people will rise, and the challenges of creating culturally relevant innovation will only increase as they leverage a global workforce to invent local solutions.

Value Chain Open Innovation (Relate).

When interviewees reflected on the path of open innovation, they perceived a new era in which a product's entire value chain would participate in innovation. Looking back, open innovation began with companies collaborating with government and university labs, then later expanded to joint ventures or alliances with single players in the value chain. Today's definition of open innovation brings employees from across the company into contact with customers in a more intimate relationship. Looking ahead, participants see the definition of open innovation continuing to expand to include collaborations of players from across the value chain, in which teams that include multiple stakeholders—from raw materials

suppliers to original equipment manufacturers to sales channels to service providers to customers—all work together to identify, ideate, and create products for quickly shifting future consumer wants and needs. Researchers will need to develop skills for working across organizational boundaries. They will be beholden to many more stakeholders and will need to know when to cooperate and when to challenge. Managers must adjust their views on IP and recognize that speed-to-market may require working efficiently with many diverse team players.

Freelance R&D (Define).

Innovation resources continue to be located outside R&D or even company boundaries. Participants see the rise of freelance R&D professionals as the global war for talent increases the options of a technically trained and experienced workforce. Technologies allowing for virtualized workers, labs, and simulations will increase the abilities of individual researchers to perform highly complex research without the need for corporate infrastructure. Participants see all of these trends combining to produce a large cadre of freelance R&D professionals who work on temporary projects anywhere in the world. These individuals may be added to internal teams or form with other temporary workers to perform specific research. After the project is done they may move on to other companies or find new projects for the current client.

For researchers, this model provides flexibility to work on topics they love without the bureaucracy. They will need to develop skills to quickly engage in projects and work independently over virtual connections. Technology managers will become the equivalent of Hollywood producers, finding and hiring a research team for each project like producers do for each movie. A skill with contracting temporary workers, especially on payments, IP, and non-disclosure will be a critical tool for success.
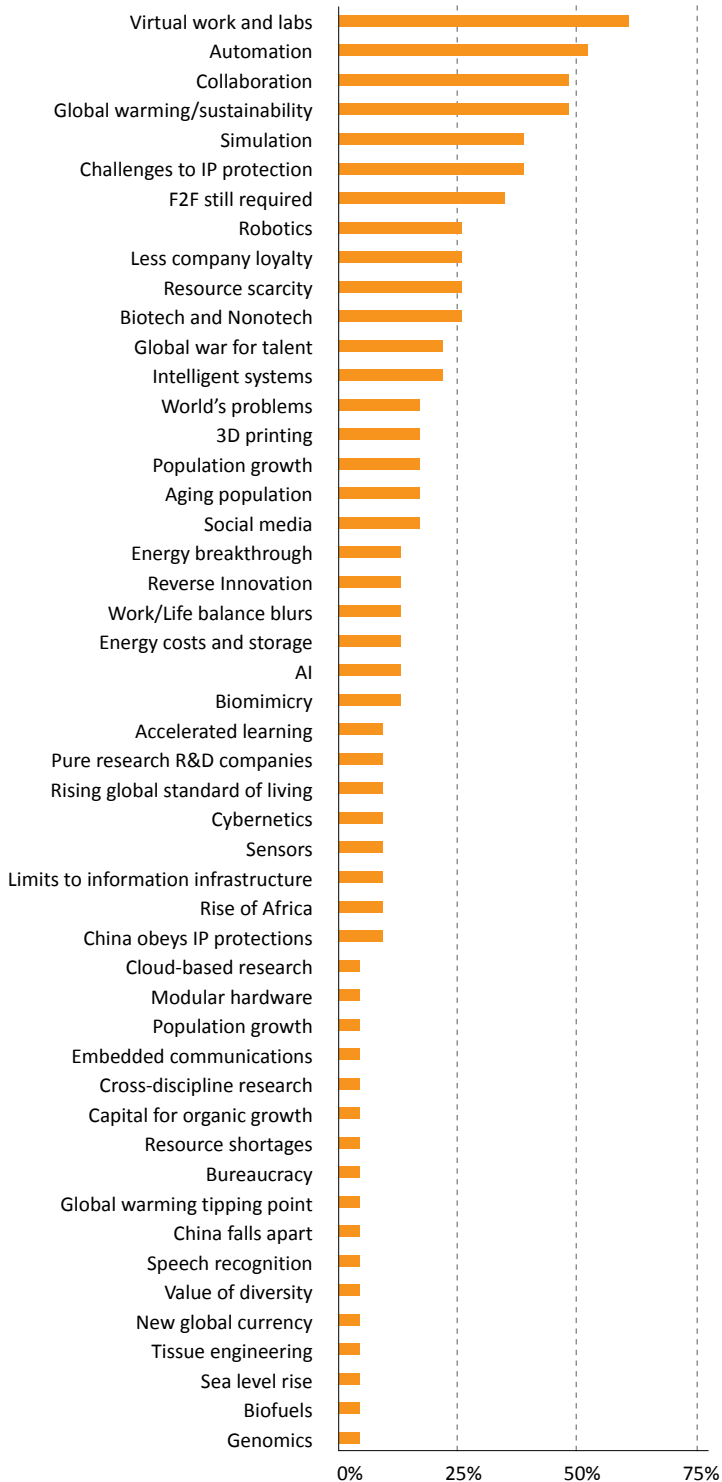
Challenges to IP (Define).

Interviewees mentioned several challenges to intellectual property protection that will grow to significantly impact future decision-making, mostly driven by globalization. As more companies around the world file for IP protections, the number and complexity of applications will overwhelm patent offices. This will cause a large delay, even more so than today, in the granting of patents. Globalization will speed up the competitiveness of markets, reducing the time companies can benefit from patents. By the time patents are granted, the customers will have moved on to new products and technologies. In emerging markets, patents may afford little protection against infringement by local competitors, reducing the value of revealing innovation in patent filings.
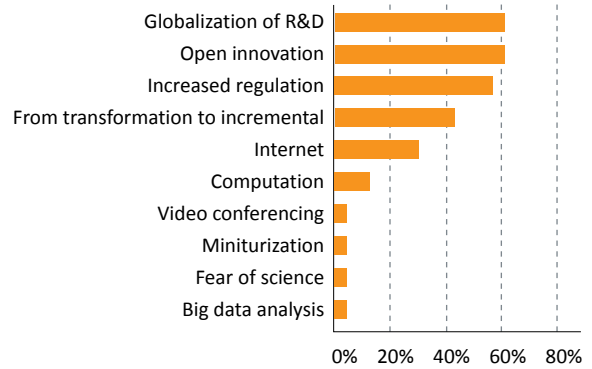
Participants suggested their companies will file fewer patents, counting instead on trade secrets and know-how to get to market first and capitalize on innovation before customers' needs and wants shift again. Importantly, interviewees from pharmaceuticals and applied chemical industries, where foundational molecules or new materials could have very long lives in the market, indicated a need to continue investing in IP protections well into the future. These participants suggested hope that signs were pointing toward better enforcement of patents globally, as more nations recognize the critical role they play in innovation.

Readers should also pay attention to the other mentioned trends about the future. These are categorized as fringe trends, but change often happens from fringe areas with low perceived probabilities of occurrence or impact. The charts shown here provide statistics for all of the trends mentioned by interviewees.
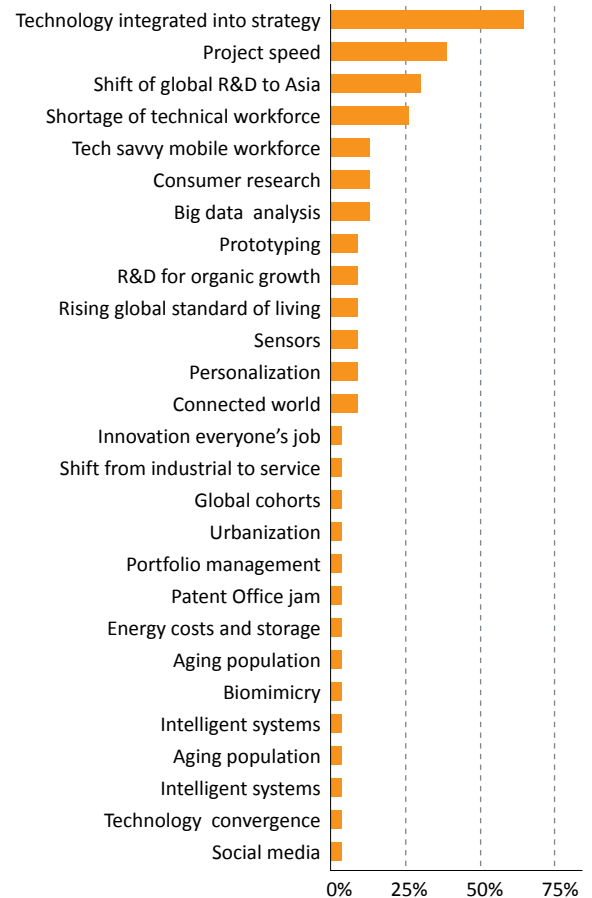
TRENDS AND ISSUES IMPACTING THE FUTURE

- Virtual work and labs
- Automation
- Collaboration
- Global warming/sustainability
- Simulation
- Challenges to IP protection
- F2F still required
- Robotics
- Less company loyalty
- Resource scarcity
- Biotech and Nonotech
- Global war for talent
- Intelligent systems
- World's problems
- 3D printing
- Population growth
- Aging population
- Social media
- Energy breakthrough
- Reverse Innovation
- Work/Life balance blurs
- Energy costs and storage
- AI
- Biomimicry
- Accelerated learning
- Pure research R&D companies
- Rising global standard of living
- Cybernetics
- Sensors
- Limits to information infrastructure
- Rise of Africa
- China obeys IP protections
- Cloud-based research
- Modular hardware
- Population growth
- Embedded communications
- Cross-discipline research
- Capital for organic growth
- Resource shortages
- Bureaucracy
- Global warming tipping point
- China falls apart
- Speech recognition
- Value of diversity
- New global currency
- Tissue engineering
- Sea level rise
- Biofuels
- Genomics

(x-axis: 0%, 25%, 50%, 75%)

TRENDS AND ISSUES IMPACTING THE PAST

- Globalization of R&D
- Open innovation
- Increased regulation
- From transformation to incremental
- Internet
- Computation
- Video conferencing
- Miniturization
- Fear of science
- Big data analysis

(x-axis: 0%, 20%, 40%, 60%, 80%)

CURRENT TRENDS AND ISSUES

- Technology integrated into strategy
- Project speed
- Shift of global R&D to Asia
- Shortage of technical workforce
- Tech savvy mobile workforce
- Consumer research
- Big data analysis
- Prototyping
- R&D for organic growth
- Rising global standard of living
- Sensors
- Personalization
- Connected world
- Innovation everyone's job
- Shift from industrial to service
- Global cohorts
- Urbanization
- Portfolio management
- Patent Office jam
- Energy costs and storage
- Aging population
- Biomimicry
- Intelligent systems
- Aging population
- Intelligent systems
- Technology convergence
- Social media

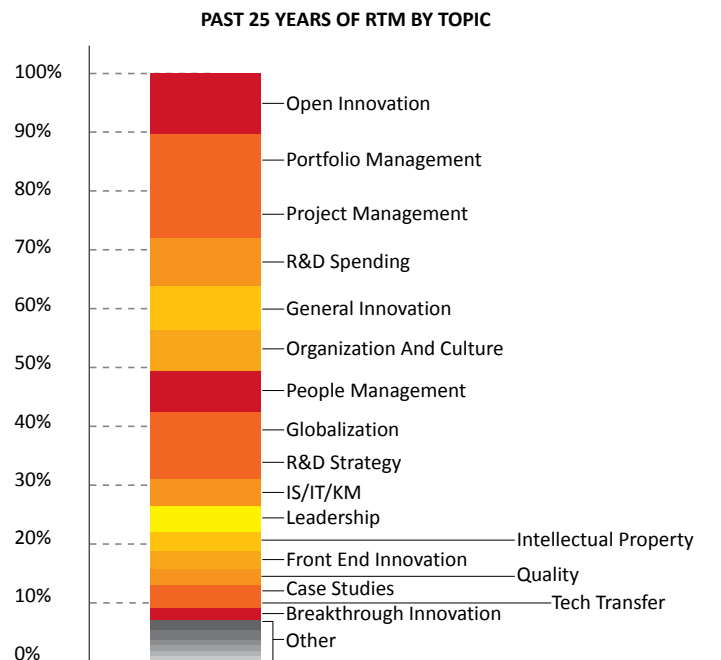*(x-axis: 0%, 25%, 50%, 75%)*

Futures Audit Conclusions

Despite the significant diversity of participants, including type of business, region of the world, and industry, there was a strong common agreement on the six drivers of change that shaped the past, the six trends impacting the field now, and the ten that will shape the next 25 years. Many participants, in fact, share three core beliefs about the impact of these trends on research and technology management.

1. **Bigger Capacity:** Technology tools and business models will dramatically increase the capacity of the individual researcher. From access to supercomputing on demand in the cloud, to inexpensive, high definition video conferencing, researchers and managers will be able to do an incredible amount of work in any location around the world. Simulation, expert systems, and robotics will also play a role to augment the future speed and effectiveness of the individual.

2. **Bigger Teams:** Research and technology managers will then increasingly be participating in temporary projects composed of representatives of the entire product or service ecosystem, some of whom will not be human. Open innovation, the war for R&D talent, and the rise of freelance R&D will mean that research teams will form from across a product or industry ecosystem to identify and solve future consumer needs. As these projects move faster from idea to market, research and technology managers will often be forming and reforming new teams to meet needs or manage difficulties of retaining talent long-term. Internal R&D departments will rely on corporate knowledge management systems to provide continuity of know-how and experience over time. These expert systems may evolve into intelligent agents able to participate fully in research teams adding to the diverse global human members that managers will need to support, motivate, and lead.

3. **Bigger Targets:** These projects will often be trying to solve bigger problems affecting the entire ecosystem or global society. The complexity of future global markets will mean that the greatest leverage for value creation will be found in solving system-wide inefficiencies. Just as iTunes broke open the digital market for songs by solving many issues across the value chain, research and technology managers will be working in these temporary teams trying to solve very big problems. Some of these problems will ascend the industry, when companies look to create value for sustainability and resource constraints that will threaten the continued growth of the global economy. This future requirement to work on system-wide solutions will counter the current trend of companies focusing on more incremental rather than transformational innovation.

The Retrospective

The retrospective report is based on IRI's journal, meeting, and working group histories. IRI's journal, _Research-Technology Management (RTM),_ was digitized going back 25 years so that a keyword search could be performed on all of its articles (over 800 in total). A similar search was performed on the last 25 years' worth of IRI's Research-on-Research (ROR) working group projects and past meeting themes. The results can be seen in the graphic below:

Subjects identified as the most significant drivers of change over the last 25 years, as identified in the retrospective, include open innovation, portfolio and project management, R&D spending changes, innovation, and organizational culture, among others. Coupled with the Futures Audit, the retrospective allowed the IRI project team to better grasp past drivers of change and correlate them with the Audit's baseline for the future as seen by its participants.

PAST 25 YEARS OF RTM BY TOPIC

- Open Innovation
- Portfolio Management
- Project Management
- R&D Spending
- General Innovation
- Organization And Culture
- People Management
- Globalization
- R&D Strategy
- IS/IT/KM
- Leadership
- Intellectual Property
- Front End Innovation
- Quality
- Case Studies
- Tech Transfer
- Breakthrough Innovation
- Other

The Weak Signals Environmental Scan

This Weak Signals Environmental Scan uncovers emerging patterns of change that are on the fringe of awareness. The Futures Audit is the primary companion to this report in the Discovery Phase of the IRI2038 project and uses interviews to establish the expected future. These two reports should be analyzed together, not separately.

Weak Signals are new patterns of emergent change. As such, there is a high amount of uncertainty about their speed, amount, and direction of change. However, they have the possibility of altering the expected future as described in the Futures Audit, and so need to be monitored and evaluated as they evolve.

There are many ways of finding and organizing weak signals in the environment. As with the Futures Audit, the Verge Ethnographic Futures Framework of Lum and Bowman was selected to help organize these signals into meaningful groups (i.e. Create, Consume, Connect, Relate, and Define). The Weak Signals report identified 23 areas of change already underway.

Create

Items grouped under the Verge category "Create" are those that reflect how we invent and build products, service experiences, and knowledge. Five potential areas of change were identified as falling under this category. The way each is presented explains how this category might affect change on our baseline view of the future. This is followed by "Scan Hits," a categorized breakdown of examples where change is happening today.

1. **Human Augmentation:** The explosion of creativity and productivity in Europe's Industrial Revolution can be traced back to the introduction of caffeine and nicotine into the diets of the intelligentsia and factory workers. More recently, pharmaceuticals meant for Attention Deficit Disorder (ADD) have been co-opted by students, professionals, and soldiers to focus attention and rapidly absorb new information. Moreover, augmented reality tomorrow will be led by the direct feed of digital information into visual and auditory human systems and the merging of biological and mechanical systems to make humans perform beyond the current limits of the body.

   Human augmentation is expected to occur in three main ways: physical augmentation of the human body, neuro-enhancement through pharmaceuticals, and augmented reality devices to overlay relevant digital information onto physical reality.

Where we see this weak signal already happening:

PHYSICAL AUGMENTATION:
- Oscar Pistorius, a double-amputee using "Cheetah Prosthetics," completed the 15th fastest 200-meter dash time in history in 2010.
- Engineers are implanting small rare-earth magnets in their fingertips to "feel" different electro-magnetic fields.
- "Cyborg tissue" has been developed at Harvard research labs.

NEURO-ENHANCEMENT:
- Over 50% of university students report having taken neuro-enhancements such as Adderall and Ritalin to help study longer, retain more information, and focus thinking; over 10% of medical professionals reported the same usage.
- An article recently reported a story about a man reprimanded for not performing at the same level as a coworker who was using illegal neuro-enhancement drugs.

AUGMENTED REALITY (AR):
- AR goggles already guide workers at Boeing when they are placing wires inside aircraft.
- Google Glass is already impacting marketing and entertainment industries in 2014.

2. **Total Simulation:** Advances in the power of computation and reductions in cost and access barriers are summoning a new wave of simulation that is available on demand for large and small companies alike. Simulated consumers will increasingly act with Turing levels of AI, allowing companies to assess the wants and needs of millions of potential customers. Quantum computing will open previously difficult computational problems to millions or billions of simulated outcomes. Almost any management or research decision will be subjected to probability analysis based on millions of simulations.

Total Simulation requires access to appropriate computing power and software that can simulate people or materials. Cloud computing is providing the access, while software to simulate people and materials is moving rapidly into R&D settings.

Where we see this signal already impacting the field of technology and research includes:

ACCESS TO COMPUTING POWER:
- **Amazon's Elastic Compute Cloud (EC2)** was launched in 2007 to give any individual or company access to thousands of PCUs.
- **CycleComputing** offers anyone access to over 50,000 CPUs for a relatively minor fee, granting even small businesses simulation capabilities formerly reachable only by large corporations and universities.
- **Cisco estimates** that by 2015, annual cloud-based computing will grow to 1.6 zettabytes of IP traffic.

SIMULATING PEOPLE AND MATERIALS:
- Google recently simulated a human brain with 16,000 CPUs and trained it to recognize cat videos.
- A virtual bot in the Unreal game convinced a panel of human judges that it was operated by a human, passing the Turing test for AI within the strict confines of an online game.
- fMRI machines are being used to map consumers' brains.
- IBM's Blue Brain project aims to simulate a fully-functional human brain by 2020 by reverse engineering it and rebuilding it with silicon chips—it has already simulated a rat's cortical column.

3. **3D Printing Pop-Up Labs:** 3D printing is a recognized disrupter to the future of manufacturing and product development. However, as it becomes more sophisticated in what it can produce and the materials it can use, 3D printing will begin to change how labs themselves are constructed. Rather than expensively made custom equipment or modified mass produced equipment, 3D printed lab tools can be cheaply made exclusively for the type of research to be done, and then recycled.

For 3D printed labs to become mainstream, advances must be seen in the complexity of the finished products, the materials 3D printers can use, and the software to guide 3D printers in advanced production techniques.

Where we see such weak scan hits already occurring includes:

COMPLEXITY:
- Medical device companies such as Stryker Industries are using 3D printing to develop customized hip and knee replacements with the ball inside the socket in the manufacturing process.
- Stratasys and Kor Ecologic recently teamed up to develop Urbee, the first car ever to have its entire body 3D printed with additive manufacturing processes (by printing layers of material on top of each other until a finished product appears).

MATERIALS:
- Advances in 3D printing techniques are enabling the use of metals, plastics, and gels to build advanced and highly resilient products.
- Titanium landing equipment parts have been created for the aviation industry.
- New chemical compounds were made possible by customized 3D printed chemical reaction vessels.

SOFTWARE:
- Botqueue is an open source program that coordinates multiple 3D Printers, enabling them to perform advanced manufacturing tasks quickly.
- Open source software for 3D printing is driving growth—Thingiverse and Makerbot websites already have lists of lab equipment designs that can be downloaded and used by anyone to create their own lab equipment.
- Organizations, such as Open Lab Idaho, are forming to guide the growth in use of 3D printers for scientific needs.

4. **Holographic Work Environments:** Videoconferencing is powering a new wave of global collaboration in R&D. Advances in bandwidth, holographic displays, and high definition cameras will shift these interactions from flat screens to 4D real-time holographic interactions. Researchers using holographic displays will interact with each other in conference rooms or within the lab itself as if they were physically co-located.

The path to fully immersive holographic labs is built on people learning to use technology to project themselves into physical spaces, to interact with holographic representations of data and objects such as prototypes or data visualizations, and to work in labs that have a mix of people and data holograms interacting together.

Where we see such weak scan signals occurring include:

HOLOGRAMS OF PEOPLE:
- Beam's Remote Presence Device allows orientation in a 3D space and the ability to look around the room and focus attention or move locations—the robot is a monitor on a motorized, self-propelled platform and is a precursor to interacting with full holograms.
- Cisco Telepresence Holograms

accomplishing the first hologram projection from California to Bangalore, placing a speaker on stage visible to participants in India.

HOLOGRAMS OF THINGS:
- Cisco's hologram system can also be used to visualize data in 3D for research purposes.

HOLOGRAMS OF ENVIRONMENTS:
- Companies such as IBM and Xerox using 3D virtual lab spaces in Second Life to pioneer team research across large physical distances. As holographic displays displace virtual environments, teams will adapt the same techniques of R&D management to an immersive holographic environment.

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5. **R&D in Space:** The advance of commercial operations in space over the next 25 years will drastically drop the cost and barriers to performing R&D in space. Most of this research will be performed by robots directed by staff on Earth or using on-board expert systems. Human researchers will learn to manipulate objects and take observations remotely. Commercial human space flight is also reducing the cost to achieve orbit and physically work in space.

Two main drivers are pushing space research further: the shift to commercial from government ventures, and the greater sophistication of robots to perform research in space's harsh environments.

We see this already occurring with these weak scan hits:

RISE OF COMMERCIAL SPACE ECONOMY:
- The global space economy grew to $289.77 billion in 2011, 41% over 5 years, powered by the commercial space industry.
- Planetary Resources is a new company that will use robots in space to mine asteroids for commodities.
- Virgin Galactic has built a spaceport in New Mexico to launch commercial space vehicles initially for tourism and private satellite launches.

ROBOTIC RESEARCH:
- NASA has detailed the advantages of research and production in low gravity or zero gravity environments for many disciplines—the International Space Station has capacity to perform research using incubators, centrifuges, and external test beds to explore biology, human physiology, and physical and material sciences.
- Robots have been exploring the surface of Mars for nearly a decade. The latest, Curiosity, can perform sophisticated analysis and has a mast to provide a view of Mars from a human height.

Consume

Items grouped under the Verge category "Consume" deal with how we acquire, use, and destroy the things we create. In more detail, this category relates to how research is used by an organization and how end-consumer consumption patterns influence R&D and technology management. Six potential areas of change identified in the Environmental Scan fall under this category.

1. **Nurturing the Data Supply Chain:** Just as organizations work to ensure that their supply chain of raw materials and other physical inputs is secure, R&D organizations will need to ensure that their incoming flow of data and information is secure. This will mean ensuring an adequate supply of data, continued access to data, quality of data, security of data, and competitive advantage through data.

We see efforts to address the data supply chain challenges in these weak scan hits:

MAKING THE DATA SUPPLY CHAIN PARALLEL THE PHYSICAL SUPPLY CHAIN:
- Apple has been cited as an organization that gains competitive advantage through optimization of its information supply chain.

MAPPING THE DATA SUPPLY CHAIN:
- NASA's Human Research Program and Space Life Sciences Directorate are mapping their human risk-related data supply chain to enhance their ability to "securely collect, integrate, and share data assets that improve human system research and operations."

REDESIGNING THE DATA SUPPLY CHAIN:
- Memorial Sloan Kettering Cancer Center undertook to redesign its patient data supply chain. Two specific goals were to encourage adoption of the open-source system by other institutions and to "do better science! (e.g. reproducible results)."
- Tessella Technology and Consulting helped Oxagen develop an integrated data pipeline to identify candidate genes from public domain genome data.

DATA SUPPLY CHAIN MANAGEMENT:
- Broadstreet Data offers tools and methods for information supply chain management and notes that one possible priority for its clients is new product development.

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2. **Perfecting Persuasion:** Persuasion is becoming more sophisticated and targeted. A global sensor network monitoring much of humanity is emerging, driven by wireless networking, development of new algorithms, and more diverse sensors. Real-time data mining on personal activities, conversations, and movement will vastly improve human health and enhance scientific understanding of human behavior, including consumer behavior. The confluence of this "big data" with developments in brain science, persuasive technology, and computing power is creating new ways to influence individuals and groups.

   Information continues to proliferate in myriad forms: biometric; cognitive; neurological; genetic; online personae; tagging; and preference trails. These developments will create a complex and visible "data picture" of our lives and will also provide the means to influence people's attitudes and behaviors profoundly.

We see this happening already with these weak scan hits:

BIOMETRIC:
- Researchers are discovering ways of using neuro-fingerprinting, using brainwave analysis to identify and map brain patterns. Such tools could help educators profile individual learners into distinctive cognitive pathways, leading to enriched and customized learning.

COGNITIVE:
- Stanford's Persuasive Tech Lab studies "the design, research, and analysis of interactive computing products (computers, mobile phones, websites, wireless technologies, mobile applications, video games, etc.) created for the purpose of changing people's attitudes or behaviors."
- Current projects include Behavior Design, Behavior Wizard, Mobile Health, Psychology of Facebook, and Peace Innovation.

NEUROLOGICAL:
- A pioneering study at UCLA and George Washington University suggests that logical persuasion (LP) and non-rational influence (NI) in advertising evoke different levels of brain activity. Researchers conclude that lower levels of brain activity from ads employing NI images tend toward less behavioral inhibition, resulting in less restraint when buying products promoted in the NI advertisements.

CONSUMER BACKLASH:
- Retail giant Target recently made headlines with their analysts' and statisticians' ability to mine the vast customer data they collect and profile their customers according to subtle changes in purchasing patterns, including in areas as personal as pregnancy. Their forecasting precision (allocating 'pregnancy prediction' scores) and targeted coupon strategies have in fact created a consumer backlash. The company now mixes coupons and ads for expectant parents with other random messages (e.g., lawnmower coupons) to ward off accusations that they know too much about the private lives of their customers.

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3. **Rise of the Lorax:** A country's most precious commodity is its natural resources. But these resources are often squandered for the enrichment of the powerful, leaving both inhabitants and environment poorer. As post-modern values begin to reshape consumers' view of their relationship with the natural world, there is an effort to recognize the rights of the natural environment under national law and constitutions. The spread of this effort as a tool to halt rapacious consumption could disrupt global commodity markets, as new questions about resources will need to be resolved.

Some rights of nature laws are already on the books, but this idea is still in its infancy. While not proposed at the international level, some UN treaties are now incorporating aspects of this idea. How these laws will be enforced is still an open question. The expansion of this idea could change the way we relate to all species, as well as how international trade is conducted.

Where we see changes within this weak signal already occurring include the following hits:

EXISTING LAWS:
- Ecuador and Bolivia have passed laws that give equal rights to nature. Under Bolivia's Law of Mother Earth, natural resources are considered a blessing and nature is guaranteed the right to life, to continue natural processes unharmed, to be free of genetic modification, and to be free of pollution.
- New Zealand has granted personhood to its Whanganui River.

ENFORCEMENT AND ITS CHALLENGES:
- India has created a National Green Tribunal which would provide a right to the environment and deal with environmental law cases.
- In Ecuador, a court ruled in favor of a river, in a case brought regarding the dumping of rock and debris from a road project, which altered the flow of the river.
- According to the Ecolabel Index, there are 432 eco-labels, originating from 246 countries, covering 25 industry sectors. Most of these labels are voluntary, meaning that companies submit their products for review to the labeling entity, but there is no legal requirement to do so. A widespread adoption of rights for nature could see many of these voluntary labels replaced by mandatory labels so as to demonstrate that the products or goods were not in violation of source country's nature laws.

FROM NATIONAL TO INTERNATIONAL LAW:
- While rights of nature statutes have been passed on a national level, there has been less success on an international level. However, ideas about the rights of nature have begun to appear in international agreements, such as the current UN climate change document, currently being negotiated.

OTHER SPECIES:
- Spain has extended human rights to great apes.
- Switzerland has extended rights to "social animals."
- There is current talk about granting rights to computers as sentient beings as these machines begin to acquire higher order intelligence.

4. **One Global System… Trillions in Savings:** R&D is increasingly spanning organizations, disciplines, and even sectors—and this is not only creating profitable opportunities for companies; it's enabling, for the first time in history, entire global systems (energy, food, healthcare, IT, etc.) to be optimized across sectoral boundaries. In fact, the next logical step in reducing costs and improving efficiency may be a global "system-of-systems" approach, which according to IBM could recapture some $4 trillion per year—wasted in today's "siloed" model—by optimizing the world's major systems at a cross-organizational, cross-sectoral level.

A system-of-systems perspective has only recently become possible, thanks to enabling technologies such as embedded sensors, massive processing power, advanced analytics, and real-time connectivity among both people and objects. Over the next decade or two, such a perspective may become crucial to managing the increasingly vast, complex, and interdependent systems that underpin the global economy.

Weak scan hits for this signal include:

$15 TRILLION WASTED:
- In today's siloed approach, major systems are optimized within particular functions, organizations, and value chains while the countless interactions and impacts among them are largely ignored. IBM estimates this siloed approach is directly responsible for systemic and inter-systemic inefficiencies that cost about $15 trillion per year (28% of global GDP). For example, more than half of the world's food supply never reaches consumers.

INCREASINGLY INTERDEPENDENT SECTORS:
- Core global systems such as healthcare, IT, water, and energy are becoming highly interdependent. In fact, an average of 47% of each core system's output depends on inputs from other systems. Food and transportation are the most dependent, with each relying on external inputs for 60% of its output.

A SYSTEM-OF-SYSTEMS CAPABILITY:
- The rise of big data is a key enabler for the system-of-systems approach. Others include advances in instrumentation (embedded sensors, etc.), interconnection (the Internet of things, the cloud, developing nations coming online, etc.), and intelligence (massive computing power, advanced analytics, etc.).

5. **Zero Waste Society:** Just as manufacturing is moving toward a closed-loop model, consumers could be called upon to do the same. "Recycle, repurpose, reuse" might become mandatory, in a new era where nothing is wasted and everyone adopts an "enoughness" mindset. Driven by regulation, changing values, emerging technology, and environmental imperatives, a truly "post-consumer society" could be in the offing.

Regulators around the world, notably in the EU, are starting to move toward zero-waste mandates—and technological innovations are emerging to meet them. Meanwhile, values like sustainability and "enoughness" are reshaping consumers' views around how they use and dispose of food, electronics, and other essential products.

Where we see this trend occurring include these weak scan hits:

REGULATORY ATTENTION TO WASTE:
- At least five EU member states (Austria, Denmark, Germany, the Netherlands, and Sweden) have already banned biodegradable waste from landfills, and all EU member states have committed to reducing food waste—at least half of which is produced by households—by 50% by 2020.
- San Francisco leads a handful of cities, including Seattle and Vancouver—and soon, Portland, Calgary, Montreal, and New York—in enacting mandatory composting.

WASTE AS A CONSUMER ISSUE:
- In the US, a 2012 poll found significant percentages of consumers expressing guilt about wasting food (39%), wasting water (27%), wasting electricity by not unplugging electronic devices (22%), failing to recycle (21%), and using plastic bags at the store rather than bringing reusable ones (20%).

SUSTAINABILITY INNOVATION:
- Design is addressing waste at every point in the consumer food chain: reduction at the source, reuse by humans or livestock, and recycling into new forms of value. Recycling food waste into energy, chemicals, and other industrial feedstocks is actually being envisioned as a new industry.
- Carol S.K. Lin, a Hong Kong scientist working with Starbucks to find new uses for spent coffee grounds, proposes "food biorefineries" to turn organic waste into industrial feedstocks.

6. **Serving a Rising Africa:** Africa is rising. Many of the fastest-growing economies in the world have been in sub-Saharan Africa over the last decade. It is benefitting from strong resource demand; interest in African agricultural potential is rising. As wages rise elsewhere, Africa could become a center for manufacturing. But it faces these opportunities with very little local research capability. (Africa will also have to overcome its vulnerabilities: it is the poorest region, and none of the nations in the region are fundamentally stable.)

African economies are growing rapidly, and a young workforce could sustain this into the future. Africa also has much of the world's underutilized agricultural potential. Africa has deep deficits to make up for in infrastructure and education. Rising prosperity and increasing outside investment can help remedy those problems.

Weak scan hits which support the signal of a rising Africa include the following:

AFRICAN ECONOMIC GROWTH:
- Since 2000, 6 of the 10 fastest-growing economies in the world have been in sub-Saharan Africa.
- Ethiopia's economy has already doubled its size in the 21st century.
- Ghana grew by 14% in 2011.
- The African middle class is also growing. Research needs for Africa's consumers and industries are likely to rise faster than innovation capabilities.

YOUNG WORKFORCE:
- Africa is the youngest continent, with a median age of 18; mortality has fallen much faster than fertility.
- Africa is currently adding 10–12 million new workers a year.

RESOURCE POTENTIAL:
- Most Africans work as famers, and Africa has 60% of the world's uncultivated arable land.

INFRASTRUCTURE CHALLENGES:
- Africa's competiveness has been held back by weak transport and energy infrastructure. Outside investment is working to change this.
- China, in 2012, offered $20 billion in loans to African countries for infrastructure and agricultural development.
- Educational infrastructure is also weak.
- One ranking found that none of the 300 most important universities are African, and only 3 of the top 500 are, and they are all in South Africa.

Connect

Items grouped under the Verge category "Connect" deal with how we communicate with people, places, and things. In more detail, this category relates to how technologies enable research collaboration, and ways that researchers connect to technologies and ideas. Six potential areas of change fall under this category.

1. **Machines Do Research:** Information technology—machines—will take an active role in R&D. IBM's Watson already combines an understanding of natural language with machine learning and the ability to formulate and test hypotheses. Eventually machines will produce design ideas with minimal human input. New roles for machines will mean new opportunities for and demands on their human partners.

   Computer systems are conducting research and making decisions with increasing autonomy, including the ability to assimilate and use massive amounts of data, search for relevant data in large, unstructured sets, create and test hypotheses, and create and optimize highly complex designs. Rights for computers and assignment of liability for the consequences of computer activities are topics of active discussion.

Weak scan hits from this signal include:

ROBOT RESEARCHERS:
- "Adam," a robotic, yeast genetics researcher created by Ross King and colleagues at Aberystwyth University, Wales, is able to generate hypotheses and design and conduct experiments to test them. Professor King believes that human and robotic scientists working together will be able to do more than either could separately.

CHEMICAL BRAINS:
- Northwestern University scientists have created a "chemical brain" dubbed Chematica, which can optimize the chemical synthesis of pharmaceuticals, identify the simplest routes to a desired end product (including "one pot" syntheses), and predict the strategy a terrorist might use to create a chemical weapon.

DIGIVIDUALS™:
- Market research firm BrainJuicer deploys DigiViduals™, "research robots conducting mass ethnography for insight generation." The technology "uses programmed research robots to search for social media content that brings a target group, attitudinal segment, trend, brand persona, or emotional territory to life through rich imagery and storytelling."

IBM WATSON'S MEDICAL DIAGNOSES:
- IBM researchers are turning the computer brainpower of the Watson supercomputer to medical diagnosis and hope to offer services to physicians within two years. IBM believes Watson will outperform other online diagnostic tools in part because of its ability to automatically assimilate medical knowledge from textbooks, publications, patient blogs, and electronic medical records.

2. **Era of Women:** The rapid rise and power of women in the corporate world, as well as prominence in other areas of society, will change social dynamics in research organizations. Women will connect in new ways, with new agendas, to shape research processes and goals in unanticipated ways. The attitudes and behaviors generally attributed to women, including collaboration, inclusiveness, mentorship, constant communication, and conviction, will be amplified as more women connect with other women in R&D.

Women's differences align with the new organizational challenges being faced. A number of studies from IBM, McKinsey, Accenture, and others highlight that for organizations to thrive in the future they will need to handle complexity, co-create with customers, create operating dexterity, and build effective and open relationships. Women excel in many of these skills.

Weak scan hits include:

POSITIVE EFFECT ON BOTTOM LINE:
- Forbes reported that "between 2004 and 2008 the top quartile of companies with the highest percentage of women directors outperformed companies in the quartile with the lowest percentage by 26%."

PRE-PROGRAMMED FOR TODAY'S CHALLENGES:
- Scientific American reports that "Females of all ages outperform males on tests requiring the recognition of emotion or relationships among other people. Sex differences in empathy emerge in infancy and persist throughout development... The early appearance of any sex difference suggests it is innately programmed—selected for through evolution and fixed into our behavioral development through either prenatal hormone exposure or early gene expression differences."

WOMEN AND ADVANCED DEGREES:
- Women now earn 60 percent of master's degrees and in 2010 their share of doctoral degrees passed 50%.
- The rate of increase in doctoral awards for women outpaces that for men in all disciplines.

MORE WOMEN PROFESSIONALS:
- Women now occupy 51% of managerial and professional jobs in the US and they dominate the fastest-growing professions.
- Nine of the 10 job categories expected to grow the most through 2020 (education, healthcare, local government, etc.) are dominated by women.
- Patents awarded to women have doubled since 1990.

DIFFERENT PRIORITIES IN LEADERSHIP TRAITS:
- A 2008 Pew Research study of 2,250 adults found that a majority of respondents believed women had stronger character traits for leadership, excelling in compassion, honesty, and creativity.

3. **Crowdfunded R&D:** Crowdfunding has primarily existed at the small and entrepreneurial scale with groupware such as Kickstarter, GoFundMe, and PleaseFundUs. Scaling up to the corporate and business level, individual investors will provide a significant voice and important funding dollars for product research. Charities and the people that support them will increasingly seek to directly fund specific research projects.

Crowdfunding is at the very early stage of maturity; expectations are that it will continue to grow rapidly in many different areas. In parallel, legislation, fraud detection, banking, credit, new models of business operations, and many other support functions, will also need to innovate.

We see such innovations in the following weak scan hits:

CROWDFUNDING IS JUST STARTING:

- ArtistShare, documented as the first crowdfunded website, was started in 2000. There are now 10 major platforms and an uncountable number of single-focus efforts.
- Crowdfunding raised $1.5 billion in 2011 and has since doubled.

LEGISLATION:

- One of the provisions of President Obama's JOBS Act is that small businesses can recruit investors to buy shares in their company.
- CircleUp is a new crowdfunded site that provides a marketplace for investors to acquire equity in private consumer product companies. Some of the current companies include pet food and baby-care products.

UNIVERSITY RESEARCH FUNDING:

- The University of Washington recently used crowdfunding to exceed their financial goals for supporting a climate change research project.
- Johns Hopkins University was able to complete its first crowdfunded gene sequencing to identify what it believes is the root cause of a young girl's problem. This approach may lead the way to exploring some of the rarer diseases.

SOCIAL INFLUENCE ON RESEARCH AREAS:

- Give.fm is linked into Facebook and provides micro-funding for common advocacy interests. Their model is to look for small ($1) recurring donations.
- Crowdfunding also allows people to pick and choose specific areas of technology that they think are important, bypassing large agencies that generally make these decisions. An example is space elevator science, a tethered tower into the sky. Currently it has 2,246 backers.

4. **Open Source Science:** Science publishing will increasingly move to open online journals and even blogs. There will be growing interest in replicating and authenticating results, creating new expectations to make available the background methodology and datasets. Open critique from online peer networks will enable researchers to improve the quality of their published research, and publicly validate the rigor of their results. New standards for data availability, archiving, and results replication will strengthen the credibility of science through greater transparency and scrutiny by a wider audience.

The open source science trend is emerging with new interest in replication studies and new standards for archiving data and making scientific research more available to a wider audience. These small initiatives have the potential to challenge the complacency of current research and bring greater scrutiny to the scientific process.

Weak scan hits for this signal include:

INTEREST IN REPLICATION OF SCIENTIFIC RESULTS:

- Science Exchange is developing a repro-ducibility initiative that coordinates the replication of scientific results with qualified research labs. The initiative is intended to highlight research labs that are producing quality results, and help to identify spuri-ous scientific findings that have crept into the literature. For example, in a cancer replication study at Amgen, only 6 out of 53 papers on cancer biology were able to be successfully replicated.

WIDER DATA ACCESS:

- The NIH is beginning to make a wider variety of clinical data available online, and non-profit journals like the Public Library of Science are making sci-entific research avail-able outside of the high-cost mainstream scientific journals.

OPEN PEER REVIEW:

- Many physicists now pre-publish their papers on the arXiv.org website, a leading open access website in the fields of physics, mathematics, computer science, quantitative biology, quantitative finance and statistics. Articles posted on arXiv are subjected to rigorous scrutiny by colleagues and peers. The feedback is used to improve the formally published article, but often much of the impact in the scientific field can occur primarily through open publishing on arXiv.

BLENDING SCIENCE PUBLICATIONS WITH BLOGS:

- Scientific American is blurring the lines between science pub-lishing and blogging by sponsoring an in-house network of science bloggers posting under the auspices of the Scientific American blog network. Scientists and field researchers can make guest blog postings and directly communicate with a wide public audience about their research projects, results, and the implications of their findings.

5. **Gamification of Research:** Research organizations can increasingly use gaming processes—rewards, goals, competition, and recognition—to structure research and spur crowd participation in innovation. This could range from problem solving and iterative testing via online games and simulations, to offering prizes for completing research milestones (e.g., the SpaceX competition). Gamified research projects will be used for internal innovation, and as a new method of R&D outsourcing.

Gamification changes the relationship of people to research tasks. It can inspire engagement by employees and others, crowdsource problem solving at different levels of complexity, generate research data, and discover people talented in research skills, including skills that research managers might not know existed.

We see gamification affecting the landscape with the following weak scan hits:

GENERATING DATA:
- Companies like Roamler allow the momentary "hiring" of thousands of people via mobile device to gather designated data, for real money and "experience points."

SOLVING COMPLEX PROBLEMS:
- Foldit is a website on which people play games involving folding structures, which represent proteins. In doing so, they are helping scientists answer difficult questions in biology. In three weeks, players discovered a structure involved in HIV that had eluded years of research.
- Another site will have players design synthetic RNA, with winning designs produced in the lab.

DISCOVERING TALENT:
- Projects like Foldit have revealed that research skills such as pattern recognition or getting people "unstuck" from a thinking rut may be found in people with no education at all in the field at hand. Gamified processes might discover gifted people automatically, including those with talents that were not being consciously sought.

INSPIRING ENGAGEMENT:
- Gamification is being used to increase workforce engagement. It is seen as a way "to inspire extreme effort, reward hard work and facilitate collaboration at unimaginable levels," as an IBM columnist put it.

6. **Islands in a Connected Stream:** The increasing connectivity of the population naturally leads to more communicating and sharing. But what if this connection represents a problem, not an opportunity? Ubiquitous connectivity means that anyone can access anything, given enough time. The world becomes ubiquitously hackable. This could result in multiple levels of connectivity within a company and within divisions. For research organizations, is being unplugged a greater benefit than being connected?

This idea is really a countertrend to current patterns. Certainly the movement is toward greater connectivity, but the threats arising from this are real. While the idea of completely disconnecting is perhaps the extreme reaction to threats from hacking incursions, there are other novel approaches to security being explored.

Weak scan hits in this signal include:

EVERYTHING IS CONNECTED:
- Cisco estimates that by 2015, there will be 25 billion devices connected wirelessly, and this rises to 50 billion by 2020. This will facilitate ubiquitous connectivity.

ANYTHING IS HACKABLE:
- Anything connected is hackable. As recent discussion reveals, not even the Mars Curiosity rover is immune to this. And, as system hacking expands, it will move from digital to the biological, as DARPA's recent "hack" of a squid's nervous system demonstrates.

AUTOMATING SYSTEMS OF TRUST:
- Systems like Connect.Me are building reputation systems leveraging transparency, a recursive credibility process and crowdsourced-recommendations to ensure trust and security of users.

NOT A WALL, A FILTER:
- Another mode of approaching security is through filtering and inoculation. Instead of building a wall to keep everything out (or in), some are creating systems that track and block proven bad actors, while at the same time using less serious infractions as a way to identify weaknesses in the security of the system.
- The OPEN Act adopts this principle, which allows maximum allocation of resources against serious threats while minor threats are treated as the inconvenience they are.

A SECOND INTERNET:
- Instead of unplugging from the Internet, forgoing the benefits of connectivity, some are calling for the creation of a second, secure Internet. In its initial phase, this would be limited to critical systems, such as power plants, other utilities, and air traffic control systems, etc. But as it grows, it could be open to businesses which want connectivity and would be willing to sacrifice some benefits for deeper security.

Relate

Items grouped under the Verge category "Relate" deal with how we affiliate with people, organizations, and social structures. In more detail, this category relates to how we build new types of organizational structures to utilize research and how we rethink our methods for hiring and compensating employees. Three potential areas of change fall under this category.

1. **New Corporate Entities:** In the United States, and many countries around the world, companies must put the interests of their primary shareholders above all other stakeholders, including citizens of the communities in which they operate, and the physical environment. It is against the law for these companies to use their resources or profits in supporting these other stakeholders in ways that do not benefit shareholders. This makes it difficult for companies to fulfill social missions as part of their operations. As a result, six states in the US and some countries around the world have changed their corporate laws, or added new legal corporate entity types, that allow companies to pursue broader missions than shareholder value. These corporate entities are opening the door for social entrepreneurs to grow their impact, and for established companies to broaden the products and services they offer that serve social as well as economic results.

   New corporate entity laws are driving corporate missions that balance the needs of the shareholder with the needs of stakeholders. This will spur new kinds of research and technology management challenges for leaders of R&D in traditional and new social benefit companies.

Weak scan hits within this signal include:

MARKET ADVANTAGES:
- **83% of US consumers** want more of the products and services they use to benefit causes.
- **62% of US consumers reported** a willingness to switch brands from one that does not have a social mission to one that does.

EMPLOYMENT ADVANTAGES:
- **Companies with social missions have higher employee retention.**
- **Engineers Without Borders USA has grown from 8 engineering students in 2002 to chapters in over 100 universities and projects in 37 countries by providing Millennial generation engineering students a social vector to their work. These young engineers look for employers who allow them to continue working toward a social good.**

SHIFT IN INNOVATION INVESTMENT:
- **US consumers are estimated to spend over $220 billion annually on goods and services related to health, the environment, social justice, and sustainable living.**
- **There are over 260 social capital investment funds investing over $200 billion.**
- **Investing in underserved communities has grown 540% over the last ten years, to almost $26 billion.**

2. **Reverse Management Innovation:** Reverse innovation, in which innovations developed for emerging markets are used to create disruptive value in mature markets, is now well-established. Companies are now learning that the management practices developed in emerging markets can also create advantage in mature markets. This is occurring in managing the innovation process itself within the organization and across the supplier ecosystem, and in the management of research professionals inside the corporation.

Reverse Management Innovation is occurring in two main areas: how innovation is managed across the ecosystem of suppliers and contractors; and in the incentives and organizational structure of R&D departments used to manage work and retain talent.

Weak scan hits include:

SUPPLIER INNOVATION:
- Chinese manufacturing has developed a program of "localized modularization" that enables innovation across a network of local suppliers. This process is cutting time to market and reducing the cost of new innovations.
- Western companies are starting to adopt this tactic to compete in home markets.

MANAGEMENT INNOVATION:
- To retain talent in emerging markets, companies are conferring symbolic titles and giving access to high-profile projects that help the local market.
- As the war for talent becomes global and research professionals are increasingly coming from Asian countries, these practices are being adopted in R&D departments in mature markets as well.

3. **Knowledge Worker Assembly Lines:** Advances in Enterprise Resource Planning programs, distributed project management software, and Knowledge Management activities within companies, are shifting the production of knowledge inside companies into an assembly line model traditionally associated with manufacturing plants. The atomization of workflow, and the high degree of coordination that project management tools are providing, will remove significant creative choices from the individual knowledge worker. As expert systems improve, knowledge workers will increasingly be managed within projects by AIs, in a similar way that voice picking systems direct humans in warehouse fulfillment roles.

Knowledge work is advancing toward assembly lines in a number of ways. Distributed Development and modular programming from the field of software is moving into other forms of innovation and product development. Online cloud-based management tools are providing advanced project management tools to smaller organizations. Finally, AI systems are arriving soon with the power to lead research projects.

Where we see such trends already occurring include the following weak scan hits:

AMAZON'S MECHANICAL TURK:
◦ **A device which leverages thousands of people to do repetitive thinking tasks that human brains are best at, for pennies an instance. There are currently over 300,000 projects being performed on** Mechanical Turk**.**

TURKIT:
◦ Turkit **is an open source program which layers on top of Mechanical Turk and can be used to conduct large research projects for journalists, with powerful results. Researchers are fed small chunks of tasks in a scheduled way, and results are combined automatically.**

MODULAR PROGRAMMING:
◦ **This breaks large software programs into smaller pieces that different programmers can do according to a schedule. Programmers no longer work on the entire program, but small pieces of it like an automobile** assembly line**.**

GITHUB:
◦ **Programs such as** Github **allow for version control and project management for modular programming across a global software coding team. Github has almost 4 million projects managed through its site.**

CLOUD-BASED PROJECT MANAGEMENT SYSTEMS:
◦ **Cloud-based systems like** Basecamp **and** TeamGantt **are lowering the cost of access for smaller R&D firms who no longer have to implement expensive Enterprise Resource Planning systems to manage the flow of research projects.**

Define

Items grouped under the Verge category "Define" deal with how we explain the world around us through concepts, ideas, and paradigms. In more detail, this category relates to how new knowledge is described and leveraged, as well as how new scientific paradigms shift our understanding of natural and social ecosystems. Three potential areas of change fall under this category.

1. **Withering of the State:** State governments are losing power at both ends of the spectrum. Within their borders, cities continue to grow in population, creating local tax revenues, municipal infrastructures, and regulatory powers for cities that rival the countries in which they are located. Outside their borders, regional economic and regulatory bodies such as the EU, NAFTA, and the African Union are the only entities large enough to tackle global issues of climate change, non-state terrorism, and technology regulation.

   Many cities in the 21st century will be as populous as many countries are today and will be where the majority of future governance issues will arise and be handled. At the same time, regional economic and regulatory blocs will handle global issues such as climate change. Companies will need to innovate within this complex new environment of regulations in which many cities and regions will replace nations.

Weak scan hits within this signal include the following:

RISE OF CITIES:
- In 2014, over 60 cities in China have populations over 1 million.
- In 2008, urban dwellers reached over 50% of the world's population.
- San Francisco, CA, has imposed strict recycle and reuse regulations for citizens and businesses and uses an online map to encourage reducing carbon footprints.
- Cities such as London and New York are regulating traffic in the city core, using data to better manage traffic flow and energy use.

RISE OF REGIONAL BLOCS:
- A troika of the EU, IMF, and European Central Bank rejected Greece's plan to cut spending and forced them to revisit their national budget.
- The African Union is developing the African Standby Force, a group of soldiers from across Africa with the mission of intervening in cross-border dispute and confronting non-state terrorism.

2. **The End of Effective IP:** The speed of today's global marketplace is forcing many companies toward open innovation. Protecting intellectual property slows down the speed and effectiveness of these innovation ecosystems, reducing a company's competitiveness in the market. In many fields, outside pharmaceuticals, companies are opting for the competitive advantage of first to market rather than the slow protection of intellectual property through patents. Even in industries in which discoveries can provide a long period of competitive advantage, many companies are opting to treat them as trade secrets rather than let the rest of the world know how to duplicate these discoveries through a patent. As a result, the concept of the effectiveness of intellectual property is dwindling worldwide.

   For many industries, patent protections are not providing competitive advantage in the marketplace. In addition, the slowness and lack of enforcement found in the global patent system is reducing the value of patents and giving competitors potentially damaging information.

Weak scan hits from this signal include:

IP NO LONGER PATH TO MARKET ADVANTAGE:
- Innovations not protected by IP, and which used groups of people instead of one lone inventor, were the most impactful and most numerous over the last 400 years.
- Eric von Hippel has declared IP a dying practice as companies get better returns on innovation investment by embracing open innovation and getting to market faster.

PATENTS NO LONGER PROTECT IP:
- Emerging markets have used lax enforcement to take mature market IP to bootstrap their economies to compete.
- Patents are no longer barriers, but instruction manuals.
- The length of time patents take to be granted reduces their useful life; the backlog in patent filings means most inventors wait 4-6 years to be granted a patent from the time of filing an application. The US now has over 600,000 patent applications pending.

3. **Anthropocene Epoch:** There is increasing evidence that humans have significantly altered the Earth's natural systems, leading many scientists and scientific bodies to adopt a new term for the geologic epoch we are currently in. Anthropocene brings together the root words "anthropo," meaning man, and "cene," meaning new. While most mark this period with the start of the Industrial Revolution, some evidence suggests humans have been altering the climate and biomes of Earth for thousands of years. This new awareness will shift humans from thinking about conservancy of the Earth, to actively managing Earth's climate and resources to mitigate the impacts of Global Warming.

This move to geo-engineering will have a major impact on R&D and technology management. Products may need to be developed with an engineered solution for remaining climate neutral, such as packaging that absorbs greenhouse gases, or made with materials that actively restore soils.

Where we see such factors occurring today include the following weak scan hits:

WEATHER MODIFICATION:
- Chemicals, such as silver iodide, shot into the atmosphere to create rain have been used for over 50 years.
- China's Weather Modification Office employs over 30,000 people and uses an array of missiles and anti-aircraft guns to seed the atmosphere. As the world's largest carbon emitter, China has the capacity, the tradition, and the need to look to bigger geo-engineering projects in the future.

EVALUATION FRAMEWORK:
- The Royal Society convened a working group and report on geo-engineering in 2009 for the purpose of creating a framework to evaluate potential large-scale applications. They cited a need for humanity to have a "Plan B" in case it proves impossible for society to slow, halt, and reverse current greenhouse gas emissions.

EXISTING RESEARCH:
- Small-scale research studies have already occurred on the two most popular geo-engineering ideas. Mesoscale iron addition postulates that large amounts of iron dumped into the cold waters of the Arctic and Antarctic oceans would create large algal blooms. These blooms could process a gigaton of carbon dioxide a year from the atmosphere.

GEO-ENGINEERED PRODUCTS:
- California considered regulating emissions from vehicles by increasing the car's paint reflectivity, but withdrew the legislation as non-cost effective.

WHITE ROOFS:
- Painting roofs in urban areas white can reduce the radiation absorbed by the earth, cut energy expenditures and cool the earth. Walmart stores have added skylights and painted roofs of their stores to save 800,000 kvh annually.

Chapter 2: Extrapolation Phase

The IRI2038 Futures Study's Discovery Phase involved collecting information about trends today that could impact the future of research and technology management. The next phase, Extrapolation, was to then take these current trends from the Futures Audit along with the potential shifts seen in the Weak Signals Environmental Scan and extrapolate them into the future to show their plausible long-term impacts on society and the profession. To do this, a foresight tool developed by futurist Joel Barker, known as Implications Wheels, was used to explore clusters of the 22 top trends from the Futures Audit and 23 areas of change in the Environmental Scan which the project leadership decided held the most potential for interaction.

The three topics explored during the Implications Wheels workshops were first introduced during an expert panel at an IRI meeting. The three speakers represented three emerging areas of change: Freelance R&D, Augmented Workforce, and Simulation. The remaining areas of future change were addressed in later workshops and online webinars.

Implications Wheels

Implication Wheels, also called "futures wheels," have been constructed to explore possible developments and implications in areas as diverse as nuclear reactor accident preparedness, the growth of charter schools, and impacts of big data on college education. They can be used in conjunction with other tools as part of an overall foresights process, as was done in IRI2038, or as a standalone device to understand the future impacts of current events and decisions.

These Implications Wheels play a critical role in the foresight process, as a single weak signal can have multiple, possibly contradictory, implications 25 years out. Implications Wheels are created in workshops, which may be held face-to-face or virtually. An Implications Wheel exercise begins with a focus on a particular weak signal or trend that has been deemed relevant based on the topic of interest, the timeframe, and customer for the project.

Any debate about whether that trend may, or may not, manifest is suspended; the signal is assumed to become a reality and its possible impacts are brainstormed. The point here is not to predict the future but to explore how it might emerge. After several direct (first-order) impacts are identified, the group and the facilitator select a few for further exploration.
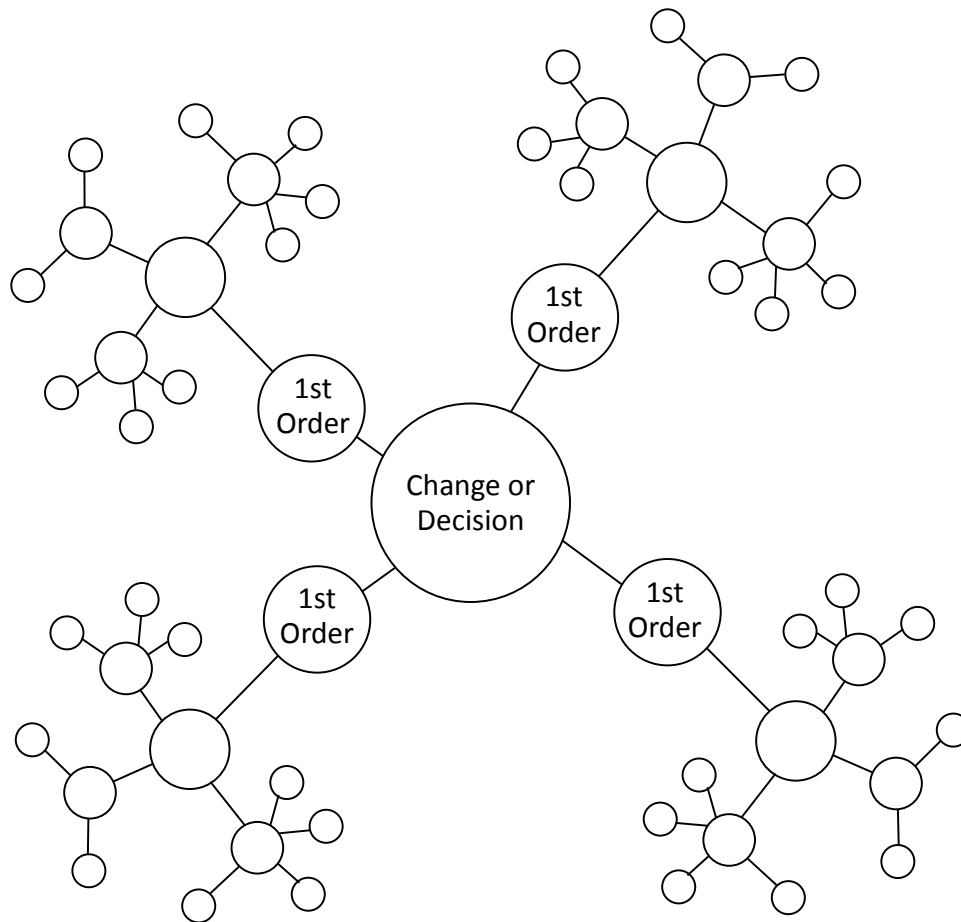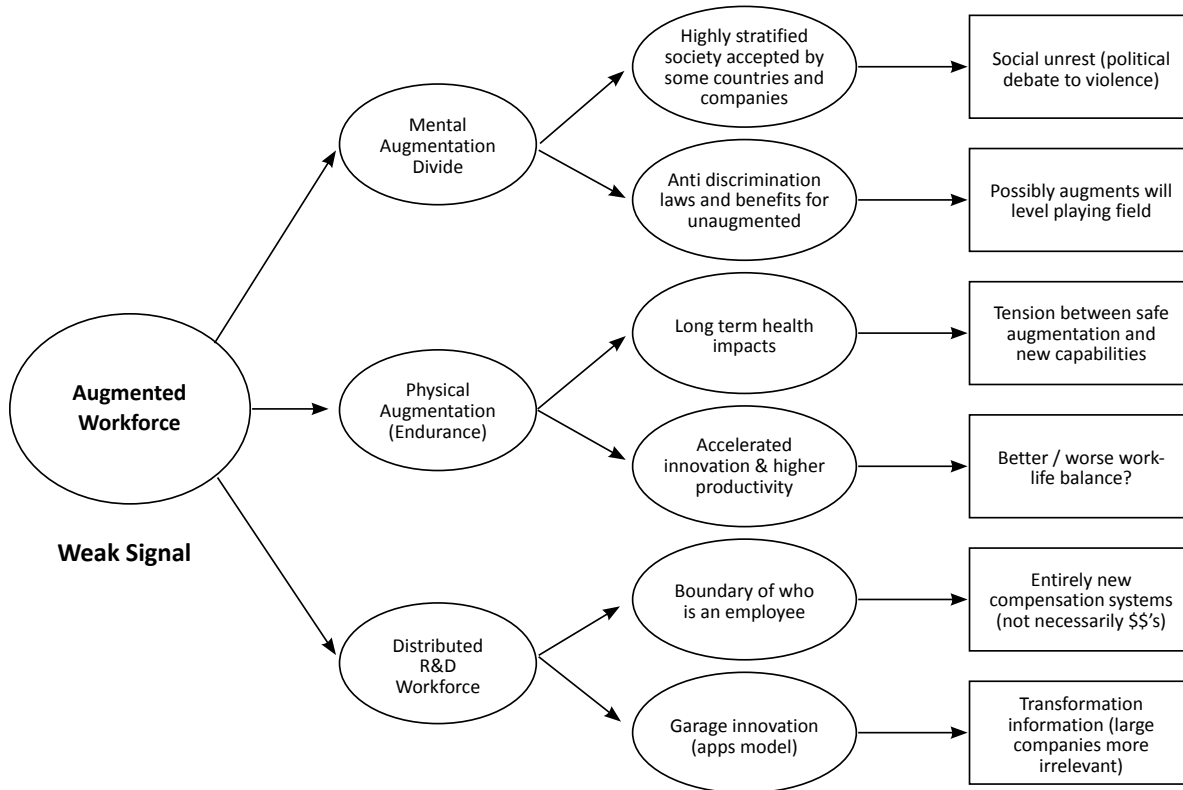
As one example from IRI2038, the weak signal "Augmented Workforce" is used to show how an Implications Wheel may be developed. For what was called the "augmented workforce" signal, the project leadership identified many possible first-order impacts:

- The use of physical augmentation to increase physical endurance and, hence, productivity;
- The development of a mental augmentation divide, similar to today's digital divide;
- The development of a distributed R&D workforce;
- The use of implants to collect direct consumer data;
- The rise of "tailoring" babies for specific jobs and roles;
- The end of the gender divide through physical augmentation;
- The extension of human life expectancy to 300 years—with all the challenges that it will bring.

The first three of these were examined more closely, primarily for their diversity and their potential to impact the future in many ways.

Implications Wheels

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                                      │ Highly stratified│      │ Social unrest    │
                                      │ society accepted │ ───▶ │ (political       │
                                      │ by some countries│      │ debate to        │
                           ┌────────┐ │ and companies    │      │ violence)        │
                           │ Mental │ └─────────────────┘      └──────────────────┘
                           │Augment-│
                           │ation   │ ┌─────────────────┐      ┌──────────────────┐
                           │Divide  │ │ Anti discrimi-  │      │ Possibly augments│
                           └────────┘ │ nation laws and │ ───▶ │ will level        │
                                      │ benefits for    │      │ playing field    │
                                      │ unaugmented     │      └──────────────────┘
                                      └─────────────────┘

                                      ┌─────────────────┐      ┌──────────────────┐
                                      │ Long term health│      │ Tension between  │
   ┌──────────────┐       ┌────────┐  │ impacts         │ ───▶ │ safe augmentation│
   │  Augmented   │       │Physical│  └─────────────────┘      │ and new          │
   │  Workforce   │ ────▶ │Augment-│                           │ capabilities     │
   └──────────────┘       │ation   │  ┌─────────────────┐      └──────────────────┘
                          │(Endur- │  │ Accelerated     │      ┌──────────────────┐
    Weak Signal           │ance)   │  │ innovation &    │ ───▶ │ Better / worse   │
                          └────────┘  │ higher          │      │ work-life        │
                                      │ productivity    │      │ balance?         │
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                                      │ Boundary of who │      │ Entirely new     │
                           ┌────────┐ │ is an employee  │ ───▶ │ compensation     │
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                           │uted    │                          │ necessarily $$'s)│
                           │R&D     │ ┌─────────────────┐      └──────────────────┘
                           │Workforce│ │ Garage          │      ┌──────────────────┐
                           └────────┘ │ innovation      │ ───▶ │ Transformation   │
                                      │ (apps model)    │      │ information (large│
                                      └─────────────────┘      │ companies more   │
                                                               │ irrelevant)      │
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In the physical augmentation sub-category, the use of augmentation technology to increase human endurance held some interesting implications for the future. Long-term health concerns could create tension between safety and the desire to gain new capabilities, as with athletic performance-enhancing drugs today. At the same time, a workforce with increased endurance should be more productive and increase the pace of innovation. But the implications for future work-life balance could be dramatic, depending on how increased endurance manifests itself and what people choose to do with their enhanced capabilities.

Within the mental augmentation sub-category, there was great concern in the workshop that it would become another driver of a "have and have not" society, based on affordability and access. Proceeding to second- and third-order impacts, would some countries promote augmentation to gain strategic advantage over other nations? Would companies do the same? Could this lead to social unrest and violence, as was seen in the case of financial stratification? One can envision governments intervening to protect the rights of the unaugmented. Implications wheels often have contradictory branches, and this debate is no exception. Participants offered a contrary possibility, that augmentation might be used primarily to assist those with some deficiency, thus contributing to a more even playing field.

Under the distributed R&D workforce sub-category, implants allowing the brain to be directly connected to the Internet or some proprietary cloud will take the virtual team concept to a whole new level. Citizen science will accelerate. Companies and other organizations, which are struggling to find breakthroughs today, will become more irrelevant to delivering future disruptive innovations and solutions to the world's grand challenges. Augmented collectives will take their place, collaborating at a more intimate level to produce new ideas. These collectives will raise fundamental questions for corporate structures. How does one define the boundary between employees and non-employees, between the company and outside, when engaging a virtual collective? And workers engaged via the collective may require new compensation systems, not necessarily based on money.

A few important points are to be made here. First, developing Implications Wheels is more art than science, involving a lot of judgment. Others may see different potential impacts or choose different ones to pursue, resulting in different scenario systems at the Integration Phase. Second, the overall foresights process is one of divergence followed by convergence. Trends and signals are prioritized throughout the process, and many are left behind. To have a manageable number of elements from which to build the scenarios, the Implications Wheels process must winnow the long list of weak signals to just a few significant impacts. However, the process may also be recursive; the trends, signals, and impacts from earlier phases may always be revisited to test the robustness of the scenarios and see if different choices lead to other interesting results.

The inductive scenarios developed in the next phase emerge from interactions among future impacts across multiple trends and weak signals. For instance, trends the group has identified as "freelance R&D" and "global war for talent" both explored the implications of workforces that exist primarily outside traditional organizational boundaries. But think on this: These impacts can only be amplified by the emergence of augmented super-humans in the workforce!

Sample sets of Implications Wheels derived by the IRI2038 Futures Study participants are below.

Once the results from these Implications Wheels were fully developed, another round of working groups used the Futures Audit, Weak Signals Environmental Scan and the Implications Wheels to develop influence diagrams that served as the building blocks of the four scenarios detailed in Section I.

Era of Women

Era of Women

Weak Signal

- Lack of support for mixed family roles
  - Re-emergence of the neighborhood → Intentional communities
  - "new families" nontraditional/friends/choice etc → Avatars to link families across distance
- Fluid, dynamic jobbing now the norm
  - Economy/talent shifts toward industries that support this → The adaptive employee
  - Talent aggregation – many different types of employees → Large organizations will shrink dramatically
- Achievement for everybody
  - Triple bottom line/stakeholder → Consensus management
  - Personal values aligned with company goals → Big rise in new for/non profit corporate structures

1st Order Impacts   **2nd Order Impacts**   **3rd Order Impacts**

Citizen Science

Citizen Science/ DIY Biotech

Weak Signal

- Disruptive new business models. Business models that are:
  - Open source, social
  - Tech club
  - Self assembly
  - Virtual
  - Cottage industry rivals Big Pharma, [& other big businesses in other sectors]
    - "Horizontals" grow: distributors, suppliers, assay providers, etc.
    - Customization increases
    - Orphan diseases treated
    - Public/private funding partnerships
  - New applications of production, marketing, and logistics strengths to exploit citizen science
    - Citizen scientists paid through a "prize" model with distributions apportioned according to relative contribution
- Citizen Science goes rogue
  - Black market healthcare [supported by an] underground economy
    - Good answers [to healthcare needs]
    - Good stuff [medicines, perhaps treatments] available cheap
    - Darwinian future [in which] increased risk [is assumed by all and some errors are fatal to those who accept treatment]
  - Enables increase in terrorism, etc. Organized crime
    - Society is "locked down" [by fears and by restrictions needed to ensure safety]
    - [New] ethical issues!

    Liability [issues must be resolved in new ways]
- Explosion of innovation
  - Cross-fertilization; silos break down
  - Radical solutions
  - Changes innovation center of mass [from traditional big/corporate science to citizen science]
  - Speed of innovation accelerates
  - Self-education [of citizen scientists]
    - New scientific revolution
    - Better, faster, and cheaper [all possible at the same time—without trade-offs among them]
    - Distribution [of citizen science results and innovation] becomes the bottleneck
    - Changes education
    - Misinterpretation [of science] issues

1st Order Impacts   **2nd Order Impacts**   **3rd Order Impacts**

Human Augmentation

```
Human Augmentation          →  Physical  →  People live "150 years"        →  World on brink of resource collapse!!!
Weak Signal                                  Greatly increased productivity →  Average work week now less than 10 hours.
                            →  Mental    →  No more mental handicaps       →  The new normal. "Normal" now seem as handicapped.
                                             Brain connected to the network. →  Knowledge loss eradicated!!
                            →  Sensory   →  Auto internal diagnostics      →  Accidents now #1 killer
                                             Super-sensor capabilities - all 5 senses →  Nobel prize for sensory integration
```

1st Order Impacts   **2nd Order Impacts**   **3rd Order Impacts**

Sustainability

```
Sustainability    →  Reduced footprint Cradle-to-Cradle lifecycle       →  Regionalization/ localization of production  →  Increased manufacturing costs, but decreased distribution costs  →  More 3D printing/ automation
Weak Signal
                  →  Major legislative impacts on products delivery
                     - no more plastic
                     - packaging
                     - energy                                           →  Across supply chain innovation               →  Brand quality without control

                  →  R&D focuses on internal processes                  →  Change how R&D value is measured              →  R&D as PR
```

1st Order Impacts   **2nd Order Impacts**   **3rd Order Impacts**

Crowdsourced R&D Funding

Crowdsourced R&D Funding

Weak Signal

New reward system for funders

Professional Crowdsourcers

"dumbing down" of R&D

Star researchers over-conpensated

Competing rewards for different industries

Crowdsource I-Banks control pricing

Demand/ requirements for transparency and accountability

Crowdsourcing meetings; quarterly Webinars

Competitive / National security source

new funding disclosure requirements

New tax rules reduces participation

Different structure and processes for internal R&D

Internal funding for long term innovation/external funding for short term projects

Less crowdsourcing participation

More transformative innovations

free-for-all project finding

Getting advance knowledge of consumer demand

1st Order Impacts   **2nd Order Impacts**   **3rd Order Impacts**

Chapter 3: Integration Phase

The image of this foresights mosaic is coming into focus. The Discovery Phase involved the collection of all our data points. The Extrapolation Phase involved building an analytical framework through which these data points could be explored. The challenge in the third phase, Integration, then is in bringing the various pieces of these frameworks together into a single product that allows participants a chance to read through, learn from, and tinker with the end product using fun, interactive tools.

The first step in integration is aggregating the narratives instigated by the Implications Wheels. The building blocks set out in this analytical framework allows the project leadership an opportunity to construct provocative, yet plausible, narratives of the future of research and technology management through influence diagrams and inductive scenarios.

Once these scenarios are built, however, they are still little more than thought exercises that are potentially enlightening if put to use. So, how can they be put to use? To make these scenarios into useful tools within any organization, a series of backcasting workshops are held in the next phase (Planning) to allow the study's participants a chance to take a scenario and work backwards at five year increments asking, "If this is where the world will be in 25 years, what must we have accomplished 20, 15, 10, and 5 years from now in order to be prepared for these coming changes?"

Influence Diagrams

Up to this point in the IRI2038 project, a Futures Audit and retrospective have delivered a baseline view of the future of the art and science of research and technology management; an Environmental Scan has pinpointed those areas which may disrupt or shift that baseline view; and, a set of Implications Wheels have explored second and third order impacts of those weak signals and global drivers of change.

A second working group session was then hosted by the IRI2038 leadership at an IRI event which asked participants to take cards with approximately 50 signals and trends identified in the three previous reports and try to plausibly link them together in an influence diagram. An influence diagram outlines ways in which drivers of change may influence one another to help create a scenario narrative. Participation was high enough that four groups were formed. Each group took the cards assigned them and began working out a scenario.

The four influence diagrams which emerged from this process formed the building blocks of the inductive scenarios that followed and which were described in detail in Section I. They are described as follows:

Africa Leapfrogs Developed Markets:

Increasing demand for more customized products drives flexible and localized manufacturing processes. With less of an installed asset base, Africa jumps ahead of the developed world in meeting customer expectations for more personalized products.
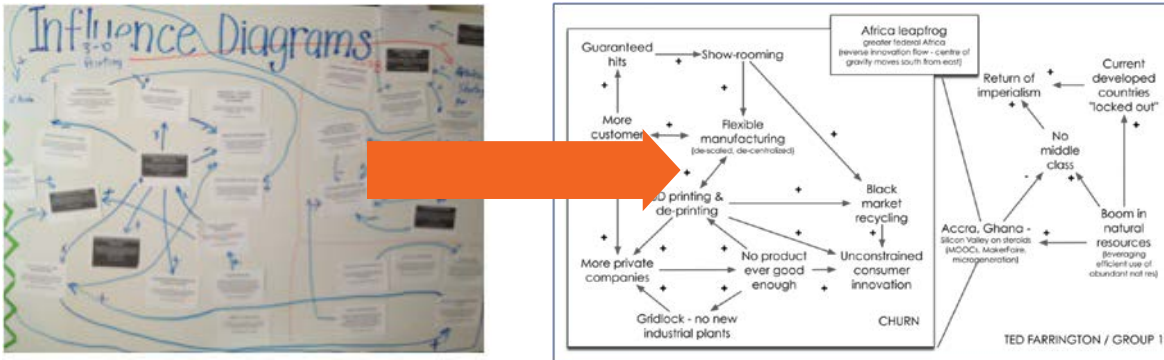
Africa Leapfrogs Developed Markets

The Death of Distance vs. Mega-Cities:

Technology and connectivity make distance irrelevant at last. Massively Open Online Courses (MOOCs) raise the education level in developing countries and mega-cities faster than at any time in history. Access to resources, not level of education, drives stratification of societies.
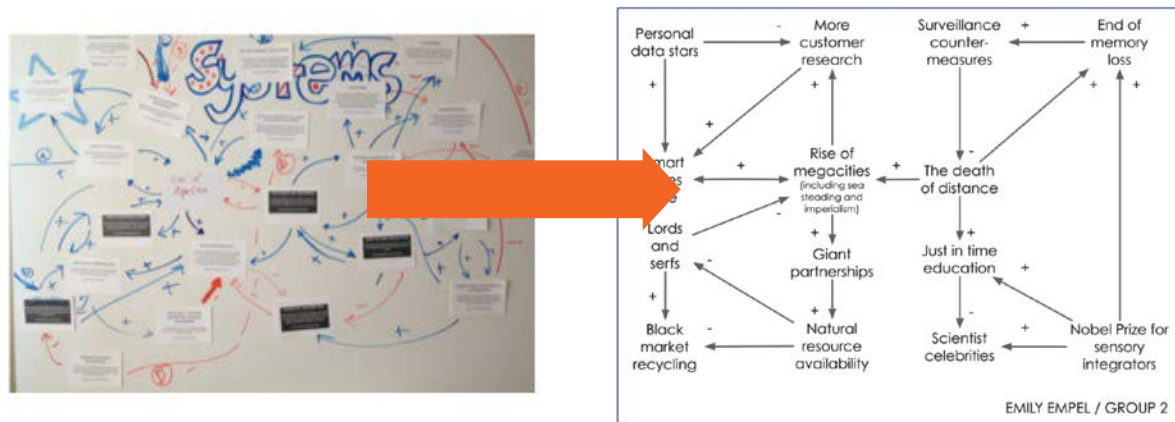
The Death of Distance vs. Mega-Cities

Three Roads to Innovation:

Research project management as we know it today is over. With the growth of freelance R&D and citizen science, the project manager's role will resemble that of a Hollywood producer today: temporarily assembling the talent and physical assets required on a project-by-project basis.
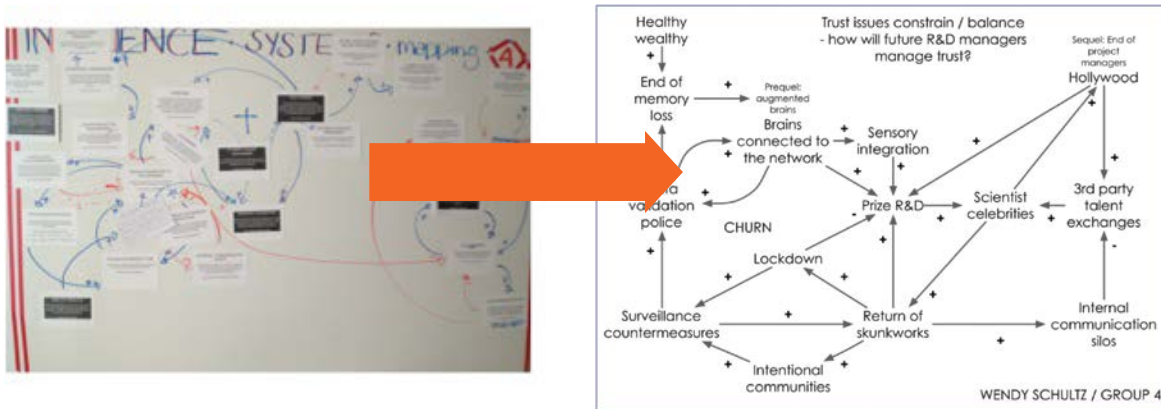
Three Roads to Innovation

Everything's in Beta:

The manufacturing ecosystem collapses as open hardware platforms and new apps flood global markets with products of questionable quality. Local manufacturing and city-based markets emerge to reclaim quality, creating opportunities for new and smaller business entities.
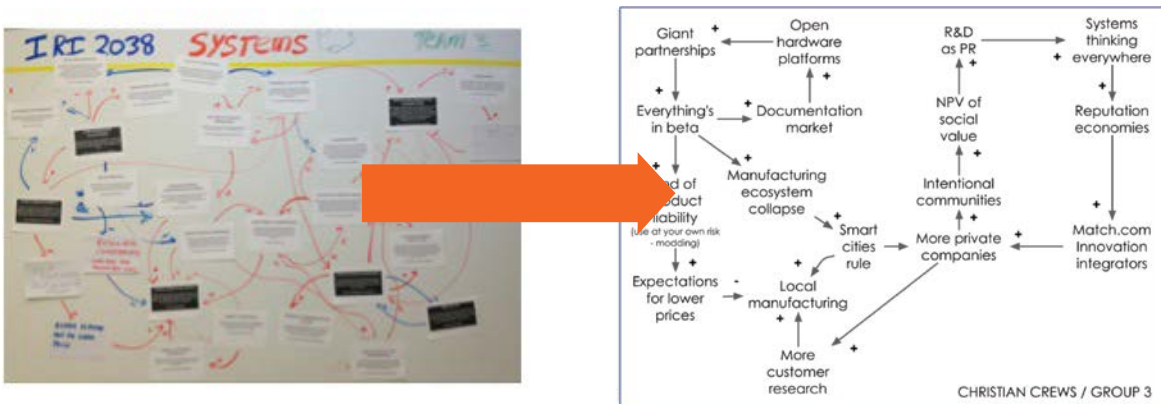
Everything's in Beta

Inductive Scenarios

Two types of scenarios are commonly used to explore the future in a structured fashion: deductive and inductive. On one hand, deductive scenarios are used to develop business strategy or evaluate the future impacts of possible decisions. Deductive scenarios involve strategists selecting the top critically uncertain trends in the external business environment, and then determining alternative futures. This is done by viewing the different ways those trends may impact the world and interact with other trends whose direction and impact are more probable. Deductive scenarios are mutually exclusive—the emergence of one scenario precludes the emergence of any others—and the scope of the scenarios is defined at the beginning of the process.

Inductive scenarios, on the other hand, emerge from the study of possible interactions among many trends and weak signals. Systems thinking methods are used to organize the interactions into causal loops that combine to form the scenario's overall system. Unlike deductive scenarios, inductive scenarios are not explicitly mutually exclusive—multiple scenarios may emerge and can coexist—and the space of the scenarios emerges during their development.

This emergent property of inductive scenarios makes them desirable for innovation and design activities. The systems thinking diagrams may suggest entirely new emerging issues and trends that could impact the future business environment. These emergent trends signal new customer needs that other methods cannot surface. Their richness of detail gives inventors and designers an intimate view of the constraints and customer pain points that may arrive in the future.

Mapping interactions of trends and weak signals in influence diagrams creates the basis for the inductive scenarios. The process begins with a collection of future trends and weak signal impacts—often developed further using Implications Wheels—and is best implemented via workshops that include diverse points of view.

Like the deductive approach, the inductive process starts by identifying future projections of strong trends, such as globalization or sustainability. However, inductive scenarios are not constrained in the number of emerging weak signal impacts that can be used to form the scenarios. In the IRI2038 process, workshop participants received a list of approximately 50 trends and weak signals in Step 1. In Step 2, they were asked to identify three to five trends or signals they believed would influence the others in a significant way.

In the graphic shown below, Steps 1 and 2 are represented by the top two quadrants. In Step 3, the lower left quadrant, participants in the workshops mapped the interaction of the various weak signals with the 3-5 identified "strong influencers." The heavy lifting in building inductive scenarios happens in Step 4, the lower right quadrant, where scenario systems maps are created to capture and simplify the essence of the influence diagrams. In the diagram below, the inductive scenario map for "Africa Leapfrogs Developed Markets" is displayed.
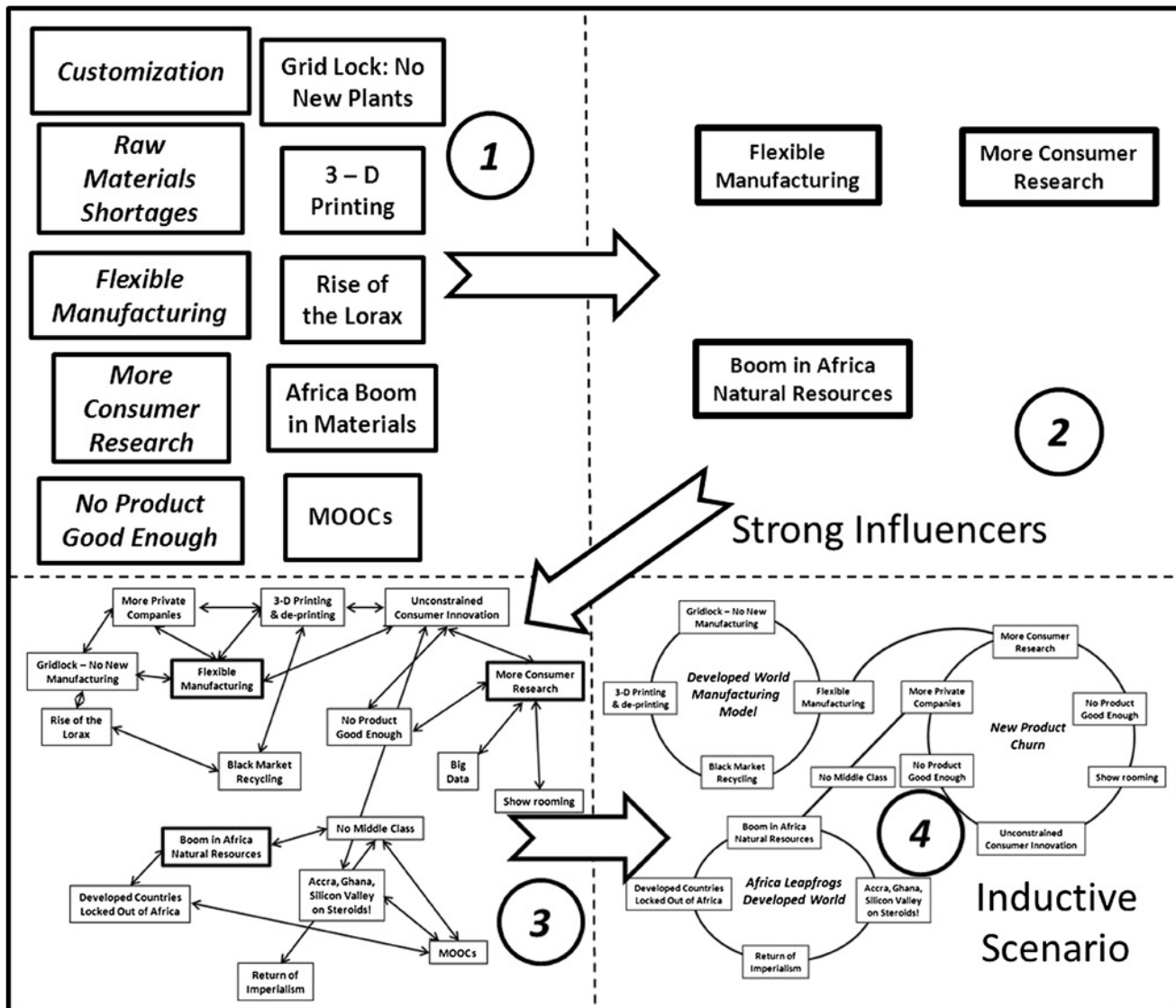
The original narrative for this scenario, developed during these workshops, was as follows: "An inability to build new capacity in the developed world due to increasing environmental regulations creates a new flexible and localized manufacturing process. This process churns out the highly customized products consumers demand at an ever-faster pace. With less of an installed asset base and the ability to better leverage its natural resources, Africa jumps ahead of the developed world in growth and economic dynamism." Notice how the keywords of this synopsis come primarily from the strong influencers of Step 2.

These influence diagrams are the feature that gives inductive scenarios their power. In the case of this example scenario, the diagram shows that this future is unresolved; different emergent drivers compete and complement each other. This competition gives insight into the constraints and customer pain points that may exist in the future. For instance, in the example, in order to succeed, companies must create R&D pro-

grams that can both navigate the power of the more traditional resource-based innovation of a growing Africa and respond to the advanced asset-less manufacturing models of slower-growth developed economies. Systems thinking techniques can be brought to bear to help identify the opportunities represented by these constraints and conflicts, places where companies can create positive change through innovation. Once the influence maps have been analyzed to find these opportunities, they then serve as the basis for clear and concise narratives about the future.

Deductive scenarios are more commonly used in futures projects than inductive scenarios, primarily because they are more well-known and easier to develop and explain. Inductive scenarios, however, more closely represent how the world, and innovation in particular, really develops: seemingly unrelated systems interact through non-obvious connections, creating change and new opportunities for innovation. From a business and innovation standpoint, every element-to-element link in a systems diagram is an opportunity to intervene and influence the system—i.e. an opportunity to innovate. From this perspective, inductive scenarios offer a much richer structure for exploration and a more sophisticated depiction of likely futures for R&D and design applications. For this reason, inductive scenarios were the best choice for exploring the future of the art and science of research and technology management.

The other three inductive scenarios used to build our foresights narratives are shown below with the descriptions written at the time of their release.

Everything's in Beta

"The collapse of the complex global manufacturing ecosystem leads to a bifurcated economy underpinned by local manufacturing. At the low end there is massive churn of new products that are introduced as beta products with little market research. On the other stand premium products that are socially reputable and deploy R&D resources towards tackling the big challenges of the 21st century."

EVERYTHING'S IN BETA
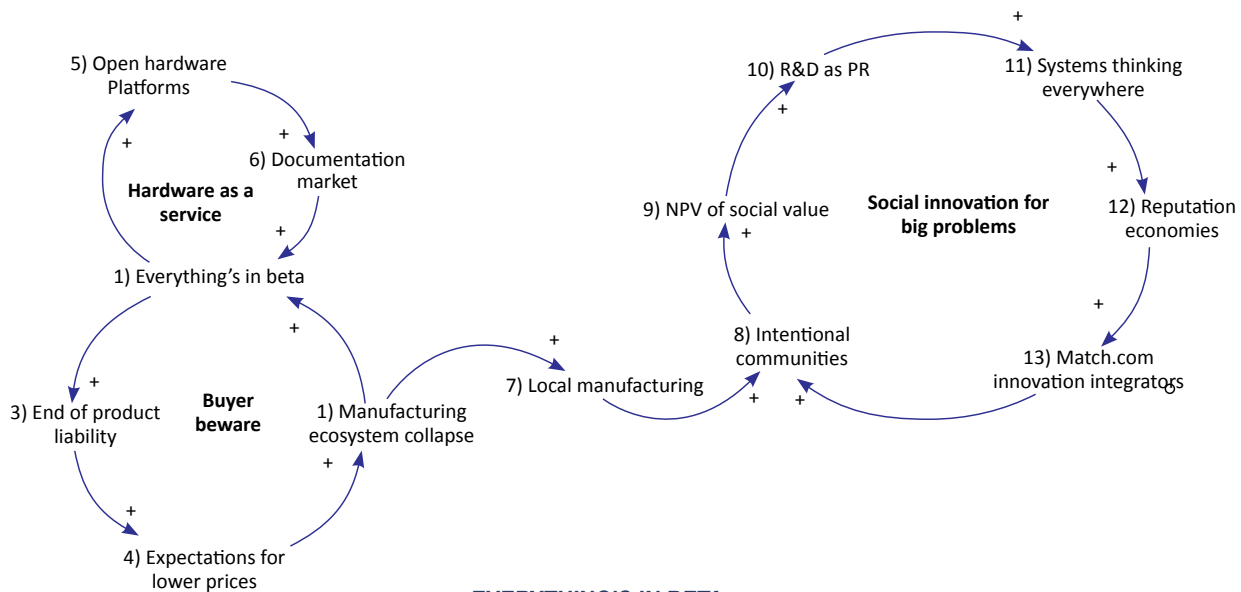
Three Roads to Innovation

"In an era of virtual work and prize driven motivation, society creates three paths toward innovation. Many choose to directly connect their brains together in a community in which the network runs project management. Another path is to intentionally form insular communities that work in secrecy. With the entire workforce now freelance, many corporations adopt a model similar to Hollywood movie studios, where a small production team manages a large pool of freelance talent."

1) Healthy wealthy

3) Sensory integration

2) Brains connected to the network

A community of minds

4) End of memory loss

5) Prize R&D

12) Hollywood

13) 3rd party talent exchanges

Hollywood R&D

11) Scientist celebrities

10) Lockdown

9) Surveillance countermeasures

6) Internal communication silos

Innovation tribes

8) Intentional communities

7) Return of skunkworks
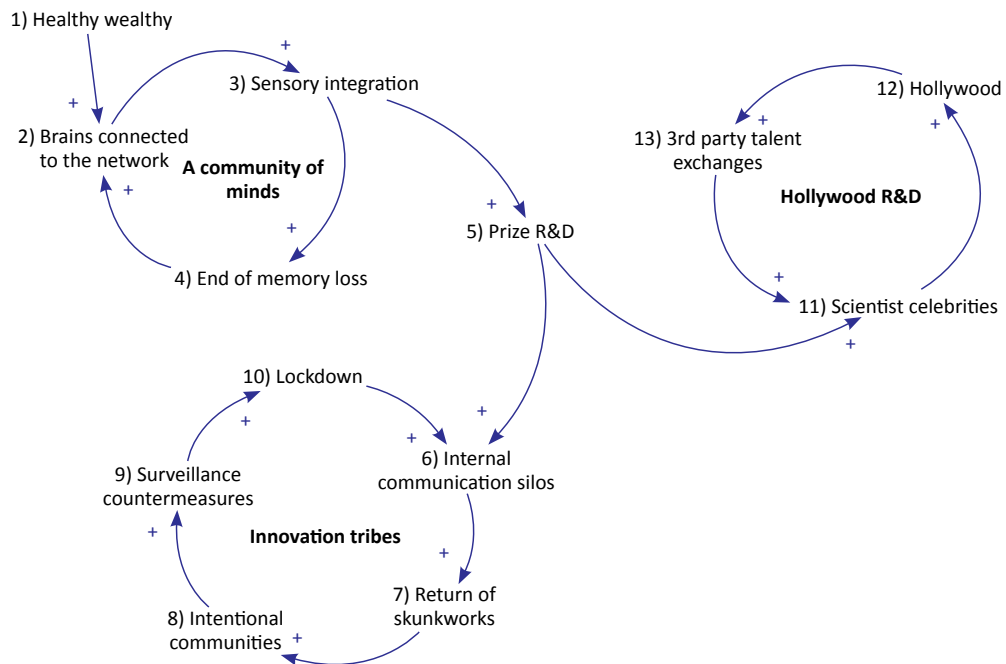
THREE ROADS TO INNOVATION

Death of Distance vs. Mega-Cities

"Cities become the major political force in countries due to their embrace of smart technologies to manage transportation, energy, and waste. They grab natural resources through giant public/private partnerships and grow into city-states. Technology and connectivity make distance irrelevant at last, restoring some balance to individuals and enabling scientists to do and teach at the level of entire corporations or universities of the past."
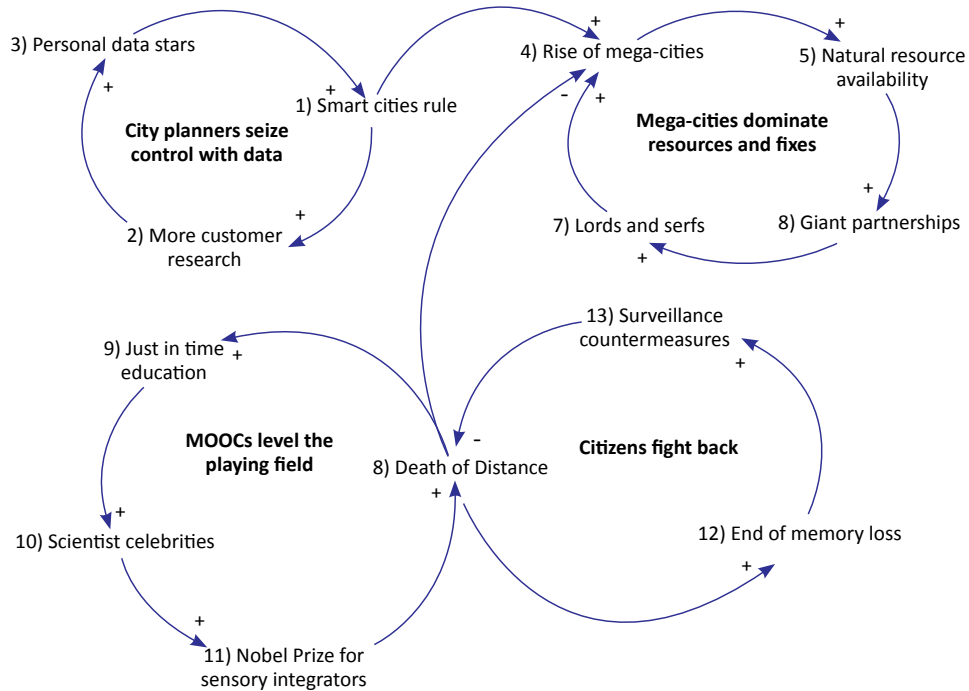
DEATH OF DISTANCE vs MEGA-CITIES

Constructing inductive scenarios, however, is only the second step of a three part process in the Integration Phase. The third portion of these scenarios is to then analyze them for significant impacts across the fields of research and technology management identified as the most relevant for practitioners. In this case, project management, portfolio management, talent management, and R&D's value proposition were cross-referenced with all four scenarios to locate and define common threads. The graphic below displays the results of this analysis.

	Africa Leapfrogs Developed Markets	Death of Distance vs Megacities	Three Roads to innovation	Everything's in Beta
Project Management	• PM by AI systems • Managers manage process (systems	• More, smaller projects • Team Assembly the core competency	• Automated stage gates • Managers pursue higher lever functions	• Fully automated PM • VERY short cycle times
Portfolio Management	• PPM by systems and big data	• Priorities set by cities and crowdsourced funding	• PPM across both open and closed projects	• PPM beta testing
R&D's Value Proposition	• Providing quick cradle to grave solutions • Not about long term IP	• R&D's value is to the megacities, not the corporation	• Identifying future opportunities	• Solving social problems • Ecosystems of external partnerships
Talent Management	• Workforce is rented, not owned • TM replaced by human capital resourcing	• Reputation market • R&D superstars • Compensation includes city perks	• Cultivating freelance workforce is key • Humans manage and managed by AI	• Bifurcated TM needs • Large social projects • Many beta projects
Overall Considerations	• More AI supporting R&D	• Megacities replace corporations as R&D's clients	• Time freed up by AI used to solve social problems	• Tow very different types of projects demand very different skills
Role of Traditional IP	• Diminished	• Must be valued by megacity	• Diminished by need for speed to market	• Gone

While the implications across these four areas of R&D management varied across each scenario, there were common themes:

- Artificial Intelligence (AI) systems will play ever increasing roles in both project and portfolio management.
- The role of traditional Intellectual Property (IP) will be greatly diminished from today.
- Talent management will be replaced by temporary resource acquisition as most of the workforce will be freelance.
- A majority of projects will become far more open, with companies relying on speed-to-market rather than IP protection for value creation.
- With AI systems leveling the field in terms of execution, R&D's value proposition will derive from early opportunity identification.
- Managers will be focused on overseeing AI process models and cultivating their external talent pool.

Chapter 4: Planning Phase

The Planning Phase sounds as if it should come at the start of a project, but the term "planning" is not used in this instance to mean planning for the project itself. Rather, it is designed to convey next steps. The building of inductive scenarios is not the end goal of a futures study; they are a starting point for a richer dialogue on strategic planning. In this portion of the project, all the heavy lifting has already been done. The data has been collected, grouped, analyzed, and displayed in narrative form through the use of inductive scenarios. Those inductive scenarios serve as the baseline for backcasting workshops which allow participants to plan more effectively for each plausible future.

Then all previous work, including the data, scenarios, and results of the backcasting workshops, are taken as the starting point for an ongoing conversation about strategic planning. The future—that elusive period—is, after all, forever an object of concern for businesses and people alike. In this phase, we ask, "Where does a project like IRI2038 go from here?"

To start, the scenarios themselves needed to be condensed into a marketable product. A collection of videos were developed in order to transform the scenarios into a multimedia package that viewers could use to present such scenario work to their own organizations.

Additionally, the early stages of the IRI2038 Futures Study included an interactive massively open online game (MOOG) to explore the future of R&D as part of the Integration Phase. The purpose of the game, Innovate2038, was to try and collect a broader set of data to support the conclusions of the project. This was to be done by opening one or more of the scenarios to the public and allowing them the opportunity to offer their take on what such a future might look like and what kinds of challenges and opportunities might arise under various conditions. The game was offered via the Foresights Engine, an online gaming platform designed by the Institute for the Future (IFTF) specifically for such purposes.

However, the results of the data took longer to analyze than was originally planned for; the game became part of the Planning Phase as a result, but not just because of the delay. The better-than-expected collection of ideas the game generated fell more broadly under the future of R&D than even the IRI2038 project itself could account for. A much wider selection of weak signals were gathered and explored in more depth by a broader cross section of global participants. Moving the game into the Planning Phase, therefore, helped create a baseline of trends and signals not included in the original product that will allow the project team more to work with as it moves forward.

Backcasting Workshops—Methodology

Backcasting originated with NASA in the 1960s when they sought out a way to map out their path to landing on the moon. They started with the assumption that they had already landed on the moon and asked what they would need to have created in order to have accomplished the landing itself. Once the landing was solved, they would ask how they got the lander into the moon's orbit. Once they figured out how to get into orbit, they would ask how they got from Earth's orbit to the moon's orbit, and so on, step by step. This process has since been adapted by futurists to help organizations envision a future of their industry, or products, and facilitate their exploration of how they might get there.

Backcasting is effective because it offers radically different paths to arrive at a target destination. This is in contrast to traditional approaches that start from today and work forward based on assumptions designed for today.

Backcasting workshops are set up as small, roundtable discussions among 6-12 individuals. The purpose is to have enough people to make the discussion diverse, but not so many that participants can get away with not contributing. The duration of the workshop can vary from one hour to several days depending on the purpose of the project and desired outcome. A moderator helps facilitate the discussion, but should try not to contribute content to the discussion unless the moderator is just as new to the content as the participants.

By the end of the session, participants should have a plan for achieving success within a particular future that shows what advances or actions must be achieved each year. Each year's set of activities should be achievable within that year, yet they build to enable the completion of an often improbable vision, such as landing a man on the moon prior to it ever having been done before.

Scenario Multimedia

As part of IRI2038's effort to create a multimedia package for the inductive scenarios, four short video summaries were produced of each scenario along with a short clip introducing the MOOG. These videos were on display during the IRI Future Summit in November 2013. The four scenario videos can be seen below, followed by Innovate2038 MOOG promotional clip.

Africa Leapfrogs Developed Markets

Death of Distance vs. Mega-Cities
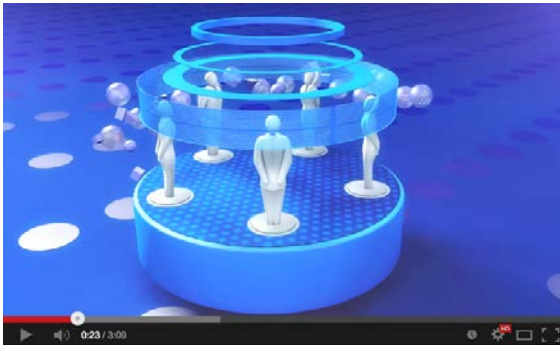
Three Roads to Innovation

Everything's in Beta
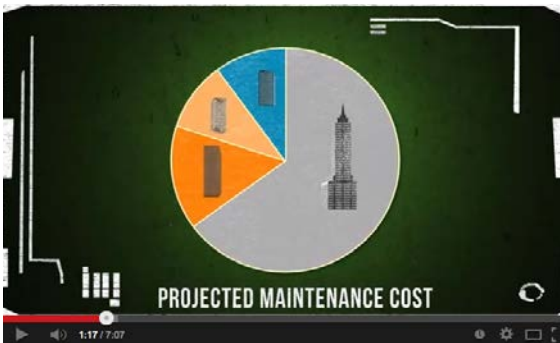
Innovate2038: The Future of Research and Innovation

The Innovate2038 MOOG

The massively open online game (MOOG) that IRI2038 offered in partnership with the Institute for the Future (IFTF), Innovate2038, exceeded all expectations. The game, open to the general public, gave participants a chance to answer two questions: "How can new research and innovation practices lead the way in 2038?" and, "What obstacles and roadblocks will hold research and innovation back?"

Players would enter 140-character length cards with their responses to either of these questions, or respond to one another in a structured gaming environment. The number of cards played and the number of response cards generated would grant players points. Participants could then compete for the top slot on the leader boards through active engagement with the MOOG.

The game was only open for a 36-hour window. Within the span of these 36 hours, 543 players from 53 countries played just under 10,000 cards with ideas, criticisms, and commentary on issues surrounding the future of R&D management. The challenge with analyzing this data is that each card is its own piece of analysis minimized to a few keywords that has to be compared and contrasted with the other roughly 10,000 cards. No easy task, but the results have been fascinating. You can read a summary of these results and the seven themes which emerged from them in Section I, Chapter 3.

IRI's Role in the Project's Future

The obvious question at this point is "What next?" The data collected and the interest of those participating at all levels of this project, as well as the opportunity for similar projects to be featured at any organization of any size, means that this project still has significant potential. IRI has chosen to take each of the different scenarios and look at them as themes (e.g. "Africa Leapfrogs Developed Markets" as geopolitics, "Everything's in Beta" as manufacturing and consumer satisfaction, etc.) in order to further explore their real-world applications. IRI will look at one theme per year as part of a Research-on-Research (ROR) working group.

The game results will also come into play as their analysis brings new light to existing trends and weak signals collected during the project's early phases. As for today, such projects become more powerful the more iteration they go through on various scales. Organizations the world over should consider running a similar project on the issues most affecting their industries.

Chapter 5: Conduct Your Own Futures Study

The unique insights derived from the IRI2038 futures study have allowed the organizations involved to develop a better understanding of potential futures. Additionally, each of these organizations now has an effective tool for broaching the topic of strategic planning in a way that produces a richer and fuller dialogue on what they need to be on the lookout for as they move ahead. But the scenarios developed, it should be remembered, are to be held as inconstant.

The danger in conducting foresights research is for organizations to treat the scenarios as the end product when, in fact, this is to the contrary. The inductive scenarios are a launching point for a greater conversation on strategic planning which only begins during the backcasting workshops. Nevertheless, developing the scenarios is part of the work that makes futures studies so fascinating. A futures study, when done well, is thought-provoking and challenging. It exposes participants to new ways of thinking about and planning for the future and in identifying blind spots or possible disruptions to their products and services. But the scenarios only fire the starting gun; they are not the race itself.

For any organizations or individuals interested in pursuing a futures study of their own, a general overview of the project's main steps and a list of questions vital to each step are included in this portion. Critical to any foresights endeavor is that it is a process, not an event. Thinking about the future in a constructive way requires a set of activities organized in a way to support ongoing strategic thinking. The United Nations University Millennium Project has identified roughly fifty foresight methods and tools. Each designed to deliver a specific output. In the construction of the IRI2038 project, IRI employed Christian Crews of AndSpace Consulting to organize the project into its four phases (Discovery, Extrapolation, Integration, and Planning). Depending on the industry and goals, different tools may be used for each of these phases. The tools used in the IRI2038 project were chosen by Crews based on the area of study and strategic uses of the product in the innovation field.
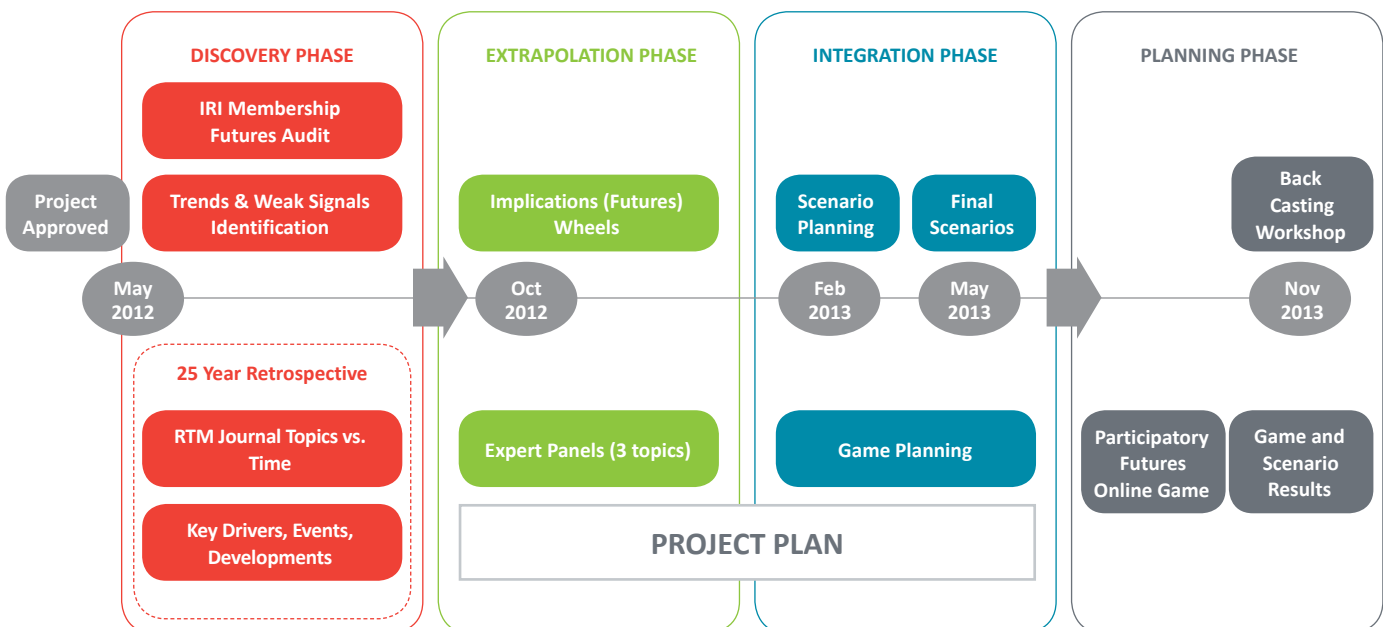
Discovery Phase

The Discovery Phase is comprised of the <u>Futures Audit</u>, <u>Retrospective</u>, and <u>Weak Signals Environmental Scan</u>. The point is to gather the tiny pieces that will be used later to build the mosaics of the inductive scenarios. Key questions to ask during this phase are:

1. What social trends and technologies developed in the last 25 years are affecting us the most today?
2. What social trends and technologies active in today's landscape carry the most potential to generate change in the future?
3. What social trends and technologies do you expect to appear in the next 25 years?
4. What economic, social, political, environmental, or technological innovations might disrupt how we conduct business or how we interact in society?

Extrapolation Phase

The second phase of a futures study is Extrapolation. In this part of the research, <u>Implications Wheels</u> are employed to explore how the pieces of data gathered from the <u>Discovery Phase</u> might play out over time. Key questions to keep in mind as you extrapolate your data into second and third order impacts are:

1. What is likely to remain the same despite technological and societal innovations?
2. What is likely to change rapidly as a result of technological and societal innovations?
3. What could be the next stage or evolution of current technology?
4. How could geopolitical changes affect the way we do business?
5. How will trends impact how we as humans: create and consume ideas, products, and services; connect and relate to people and institutions; and, define our world.

Integration Phase

The Integration Phase is where the pieces collected and extrapolated start to come together into scenarios and provide a framework for the backcasting workshops. Key questions during this phase are:

1. Within the dataset, what pieces appear to fit together best?
2. What pieces appear to fit together the least (i.e. which pieces contradict)?
3. How do the first, second, and third order impacts interact to create a plausible scenario?
4. Which scenarios are the most plausible?
5. Using incasting, read a description of the most plausible scenario to small groups, then ask: What are the implications of this scenario on education? Technology? Science? Environment? Public policy? Employment? Communication? Government?

Planning Phase

The final phase of a futures study involves planning core and contingency strategies based on the completed scenarios. Key questions to bear in mind are:

1. What common themes do you see running through each scenario?
2. Which trends will have the greatest impact on society? Technology? Your business?
3. What are the practical applications for your organization?
4. How does your organization spot additional changes not developed in the scenario process?
5. How can you improve on your existing strategic plan considering all that you have learned?
6. What changes, if any, should you make to your organization considering the implications of your scenarios?

Resources

Futures studies consist of methods developed and designed over the last few decades by academics and futurists. Each phase of the IRI2038 project is itself built atop several methods (e.g. Futures Audit, Implications Wheels, etc.) designed for a specific purpose. How these pieces fit together to form an effective futures study is a task typically left to professional futurists, but a wide variety of resources exist that help lay the groundwork and to understand how the various methods can aid one's journey into the world of foresights research and strategic planning. The following list is comprised of the resources used or developed by the IRI2038 project leadership when planning and executing this project.

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ENDNOTES

1. "Gridlock," a third order impact from the "Rise of the Lorax" Implications Wheel.

2. "3D Printing and De-Printing," a third order impact from Zero Waste Society.

3. "Black Market Recycling," from Zero Waste Society.

4. "Flexible Manufacturing," from Simulation.

5. "More Customer Research," from Withering of the State.

6. "Guaranteed Hits," from Crowdfunded R&D.

7. "Show Rooming," from Zero Waste Society.

8. "Unconstrained Consumer Innovation," from Zero Waste Society.

9. "No Product Ever Good Enough," from Simulation.

10. "More Private Companies," from Islands in a Connected Stream.

11. "Boom in African Natural Resources," from Serving a Rising Africa.

12. "Locked Out!" from Serving a Rising Africa.

13. "Return of Imperialism," from Rise of the Lorax.

14. "Accra, Ghana: Silicon Valley on Steroids," from Serving a Rising Africa.

15. "No Middle Class," from Resource Constraints.

16. "Smart Cities Rule," a third order impact from the Withering of the State Implications Wheel.

17. "Personal Data Stars," from Nurturing the Data Supply Chain.

18. "More Customer Research," from Withering of the State.

19. "Rise of Mega-Cities," from Withering of the State.

20. "Natural Resource Availability," and "Return of Imperialism," from Rise of the Lorax.

21. "Giant Partnerships," from Anthropocene Epoch.

22. "Lords and Serfs," from Resource Constraints.

23. Death of Distance," from Robotics and Automation.

24. "Just in Time Education," from Robotics and AI.

25. Based on the idea of the "Turing Test" postulated by Alan Turing in 1950 where an AI is capable of making a human judge unable to determine whether the "individual" on the other end of a virtual communication is human or machine.

26. "Scientist Celebrities," from Virtual Workforce and Labs.

27. "Nobel Prize for Sensory Integrator," from Human Augmentation.

28. "End of Memory Loss," from Human Augmentation.

29. "Surveillance Countermeasures," from Perfecting Persuasion.

30. "Healthy Wealthy," a third order impact from the Bio & Nano Technology Implications Wheel.

31. "Brains Connected to the Network," from Human Augmentation.

32. "Nobel Prize for Sensory Integrator," from Human Augmentation.

33. "End of Memory Loss," from Human Augmentation.

34. "Prize R&D," from Open Source Science.

35. "The Return of Skunkworks," from Islands in a Connected Stream.

36. "Intentional Communities," from Era of Women.

37. "Surveillance Countermeasures," from Perfecting Persuasion.

38. "Lockdown!" from Open Source Science.

39. "Internal Communication Silos," from Reverse Management Innovation.

40. "Scientist Celebrities," from Virtual R&D Workforce and Labs

41. "Hollywood!" from Freelance R&D.

42. "Third Party Talent Exchanges," from Freelance R&D.

43. "Manufacturing Ecosystem Collapse," a third order impact from the Zero Waste Society Implications Wheel.

44. "Everything's in Beta," from Challenges to IP Protection.

45. "End of Product Liability," from Zero Waste Society.

46. "Expectation of Lower Prices," from Challenges to IP Protection.

47. "Open Hardware Platforms," from Value Chain Open Innovation.

48. "Documentation Market," from 3D Pop-Up Labs.

49. "Local Manufacturing," from Sustainability.

50. "Intentional Communities," from Era of Women.

51. "The NPV of Social Value," from New Corporate Entities.

52. "R&D as PR," from Sustainability.

53. "Systems Thinking Everywhere," from New Corporate Entities.

54. "Reputation Economies," from Challenges to IP Protection.

55. "Match.com Innovation Integrators," from Value Chain Open Innovation.