Setting the Stage: Modelling and Visualizing Science and Technology Developments

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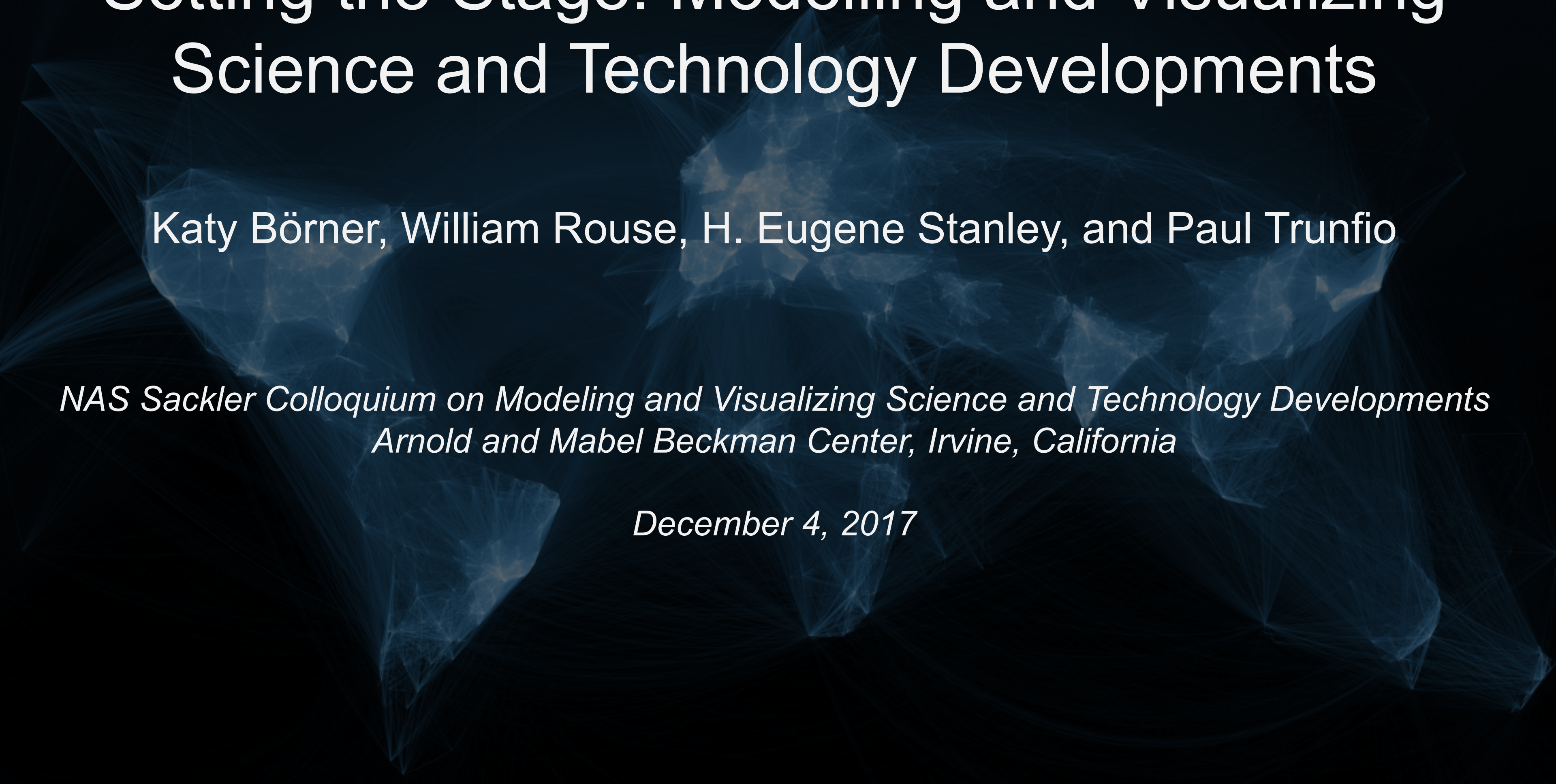
NAS Sackler Colloquium on Modeling and Visualizing Science and Technology Developments
Arnold and Mabel Beckman Center, Irvine, California

December 4, 2017



Olivier H. Beauchesne, 2011. Map of Scientific Collaborations from 2005-2009.

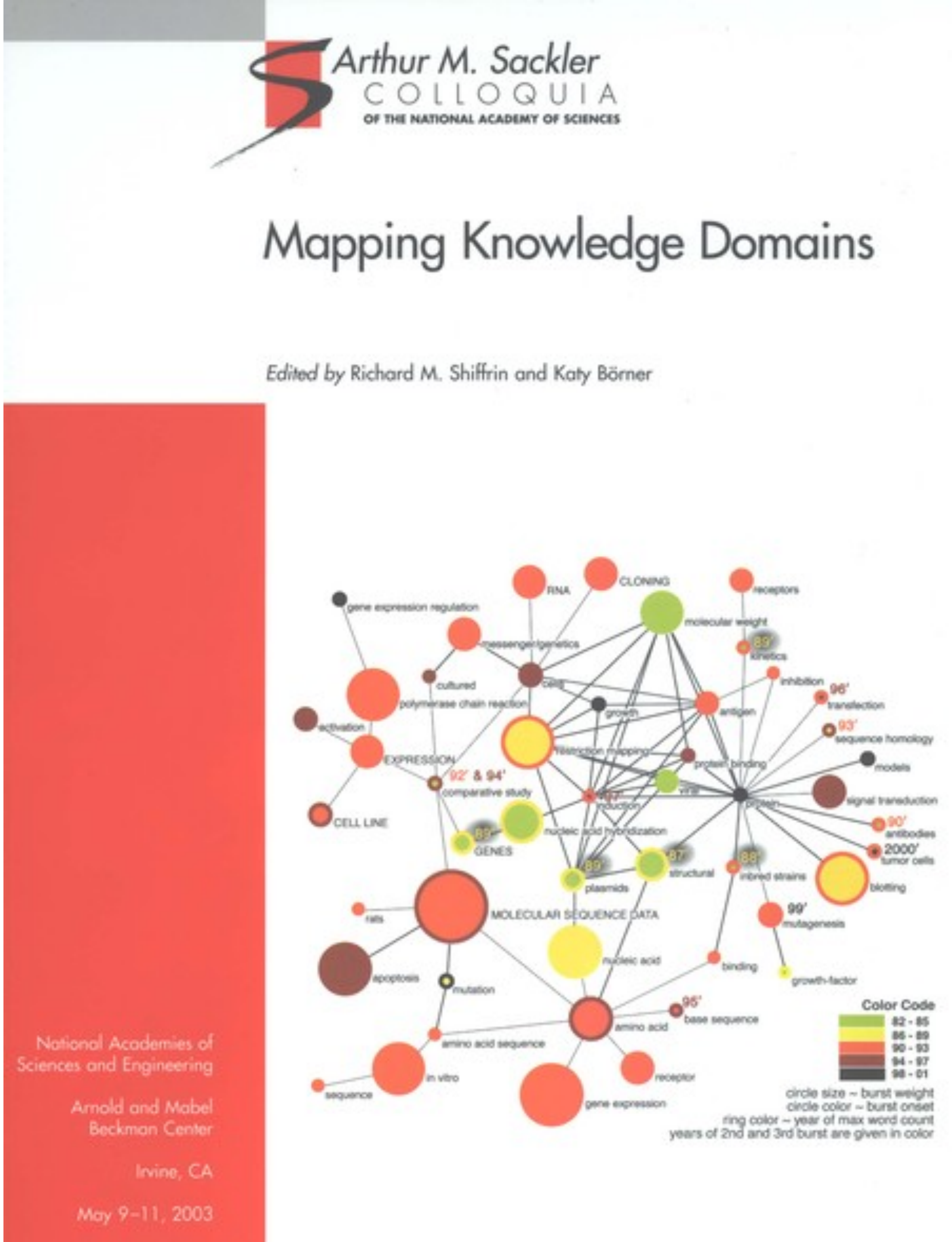
Computed Using Data from Elsevier's Scopus

14 years ago:

The Arthur M. Sackler Colloquium on **Mapping Knowledge Domains** was held at the Arnold and Mabel Beckman Center of the National Academies of Sciences and Engineering in Irvine, CA, May 9–11, 2003.

It showcased ongoing developments in this research area and provided pointers toward future developments.

136 pages
https://doi.org/10.17226/11048



Widely Used Models

Weather Forecast

Oil Depletion

Seismic Hazards

Epidemic Models

Chess Playing and Other Gaming Models

Computed Using Data from Elsevier's Scopus

Irvine, CA 10 Day Weather

6:16 am PST Print

Retrieved on 11/25/2017, 9:27am

DAY	DESCRIPTION	HIGH / LOW	PRECIP	WIND	HUMIDITY
TODAY NOV 25	Sunny	82°/55°	0%	S 6 mph	53%
SUN NOV 26	Sunny	77°/58°	0%	WSW 6 mph	62%
MON NOV 27	Partly Cloudy	67°/49°	20%	WSW 12 mph	62%
TUE NOV 28	Partly Cloudy	76°/51°	0%	S 6 mph	32%
WED NOV 29	Partly Cloudy	73°/53°	0%	SSE 6 mph	47%
THU NOV 30	Mostly Cloudy	73°/53°	0%	SSE 6 mph	53%
FRI DEC 1	Partly Cloudy	71°/53°	10%	SSE 6 mph	63%
SAT DEC 2	Showers	67°/51°	60%	SSE 7 mph	76%
SUN DEC 3	Partly Cloudy	69°/50°	20%	SSE 5 mph	61%
MON DEC 4	Showers	68°/50°	40%	SE 8 mph	62%
TUE DEC 5	Partly Cloudy	66°/48°	20%	SE 5 mph	62%
WED DEC 6	Partly Cloudy	68°/50°	20%	ESE 7 mph	62%
THU DEC 7	Mostly Sunny	69°/51°	10%	ENE 7 mph	57%
FRI DEC 8	Partly Cloudy	70°/52°	0%	ESE 7 mph	54%

https://weather.com/weather/tenday/l/USCA0517:1:US

Irvine, CA 10 Day Weather

6:20 am PST6:14 am PST   Print

Retrieved on 12/03/2017, 9:28am

DAY	DESCRIPTION	HIGH / LOW	PRECIP	WIND	HUMIDITY
TODAY DEC 3	Partly Cloudy	69°/51°	10%	SSW 7 mph	76%
MON DEC 4	Partly Cloudy	73°/52°	0%	ENE 18 mph	18%
TUE DEC 5	Partly Cloudy/Wind	74°/49°	0%	NE 23 mph	11%
WED DEC 6	Sunny	77°/53°	0%	NNE 7 mph	16%
THU DEC 7	Partly Cloudy	79°/53°	0%	NE 9 mph	16%
FRI DEC 8	Partly Cloudy	80°/52°	0%	NNE 6 mph	19%
SAT DEC 9	Partly Cloudy	78°/53°	0%	E 5 mph	24%
SUN DEC 10	Partly Cloudy	76°/53°	0%	S 4 mph	27%
MON DEC 11	Sunny	74°/53°	0%	SSW 5 mph	27%
TUE DEC 12	Mostly Sunny	75°/54°	0%	SSW 5 mph	35%
WED DEC 13	Mostly Sunny	76°/54°	0%	SSE 5 mph	38%
THU DEC 14	Sunny	76°/54°	0%	SSW 6 mph	40%

https://weather.com/weather/tenday/l/USCA0517:1:US

Irvine, CA 10 Day Weather

6:16 am PST Print

Retrieved on 11/25/2017, 9:27am

DAY	DESCRIPTION	HIGH / LOW	PRECIP	WIND	HUMIDITY
SUN DEC 3	Partly Cloudy	69°/50°	20%	SSE 5 mph	61%
MON DEC 4	Showers	68°/50°	40%	SE 8 mph	62%
TUE DEC 5	Partly Cloudy	66°/48°	20%	SE 5 mph	62%
WED DEC 6	Partly Cloudy	68°/50°	20%	ESE 7 mph	62%

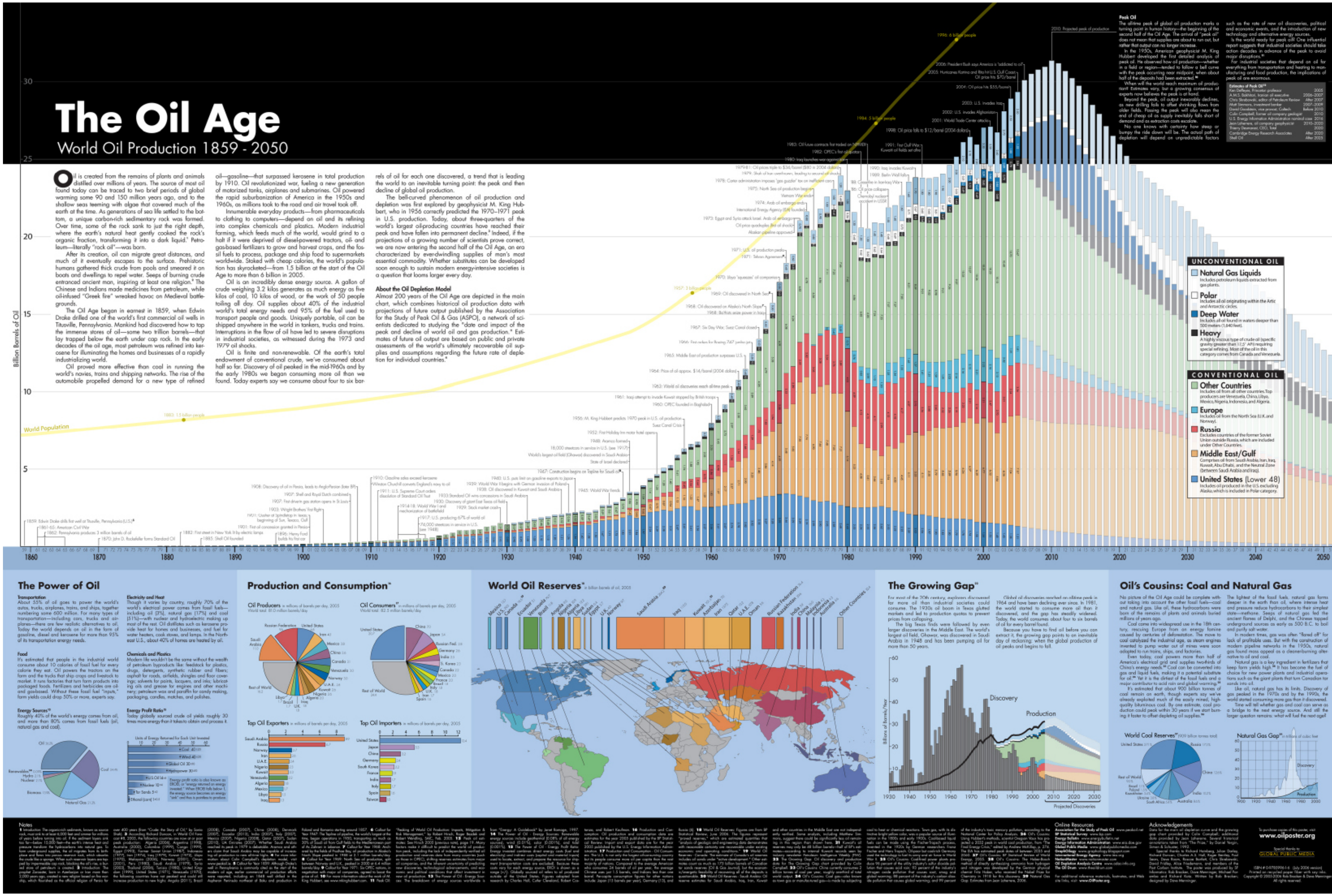
Irvine, CA 10 Day Weather

6:20 am PST6:14 am PST Print

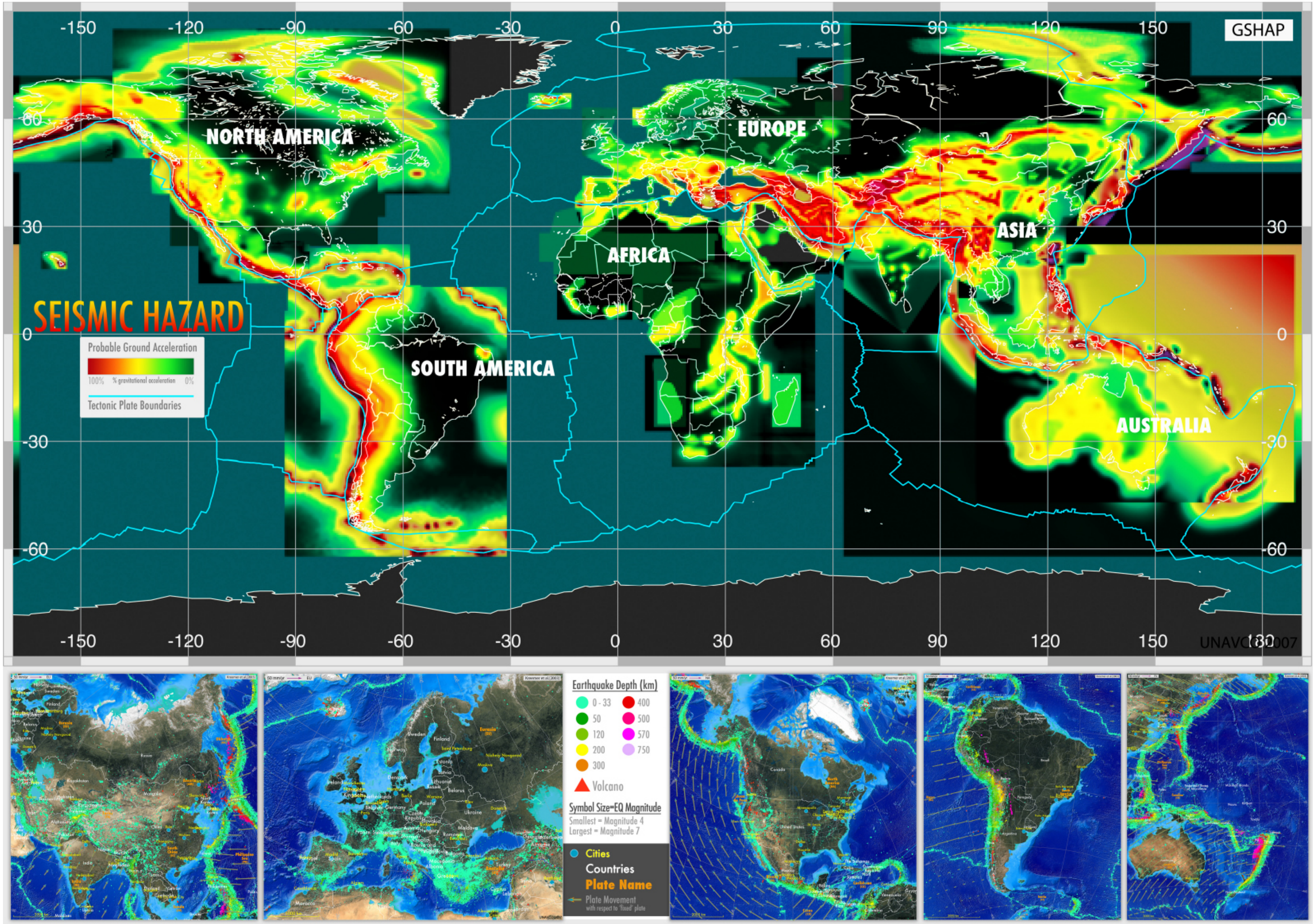
Retrieved on 12/03/2017, 9:28am – 8 days later

DAY	DESCRIPTION	HIGH / LOW	PRECIP	WIND	HUMIDITY
TODAY DEC 3	Partly Cloudy	69°/51°	10%	SSW 7 mph	76%
MON DEC 4	Partly Cloudy	73°/52°	0%	ENE 18 mph	18%
TUE DEC 5	Partly Cloudy/Wind	74°/49°	0%	NE 23 mph	11%
WED DEC 6	Sunny	77°/53°	0%	NNE 7 mph	16%

https://weather.com/weather/tenday/l/USCA0517:1:US



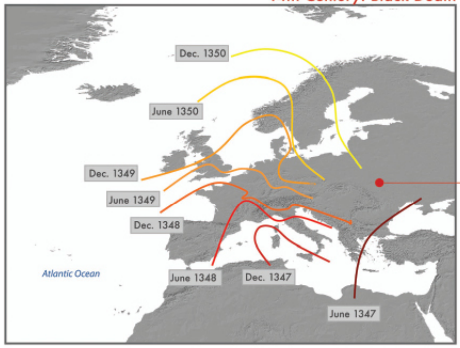
III.2 *The Oil Age: World Oil Production 1859-2050* - Rob Bracken, Dave Menninger, Michael Poremba, and Richard Katz - 2006



III.1 *Tectonic Movements and Earthquake Hazard Predictions* - Michael W. Hamburger, Chuck Meertens, and Elisha F. Hardy - 2007

Impact OF Air Travel ON Global Spread OF Infectious Diseases

14th Century: Black Death

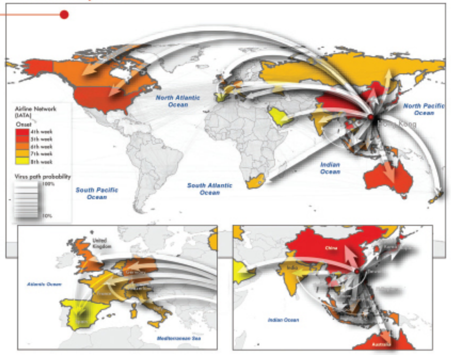


Epidemic spreading pattern changed dramatically after the development of modern transportation systems.

In pre-industrial times disease spread was mainly a spatial diffusion phenomenon. During the spread of Black Death in the 14th century Europe, only few traveling means were available and typical trips were limited to relatively short distances on the time scale of one day. Historical studies confirm that the disease diffused smoothly generating an epidemic front traveling as a continuous wave through the continent at an approximate velocity of 200-400 miles per year.

The SARS outbreak on the other hand was characterized by a patched and heterogeneous spatio-temporal pattern mainly due to the air transportation network identified as the major channel of epidemic diffusion and ability to connect far apart regions in a short time period. The SARS maps are obtained with a data-driven stochastic computational model aimed at the study of the SARS epidemic pattern and analysis of the accuracy of the model's predictions. Simulation results describe a spatio-temporal evolution of the disease (color coded countries) in agreement with the historical data. Analysis on the robustness of the model's forecasts leads to the emergence and identification of epidemic pathways as the most probable routes of propagation of the disease. Only few preferential channels are selected (arrows; width indicates the probability of propagation along that path) out of the huge number of possible paths the infection could take by following the complex nature of airline connections (light grey, source: IATA).

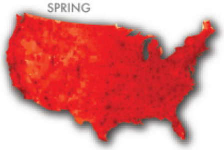
21st Century: SARS



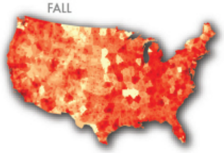
Forecasts OF THE Next Pandemic Influenza

Seasonal

SPRING



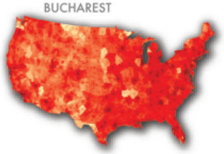
FALL



Geographical

CHICAGO

BUCHAREST

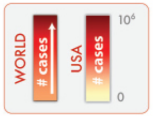


Forecasts are obtained with a stochastic computational model which explicitly incorporates data on worldwide air travel and detailed census data to simulate the global spread of an influenza pandemic.

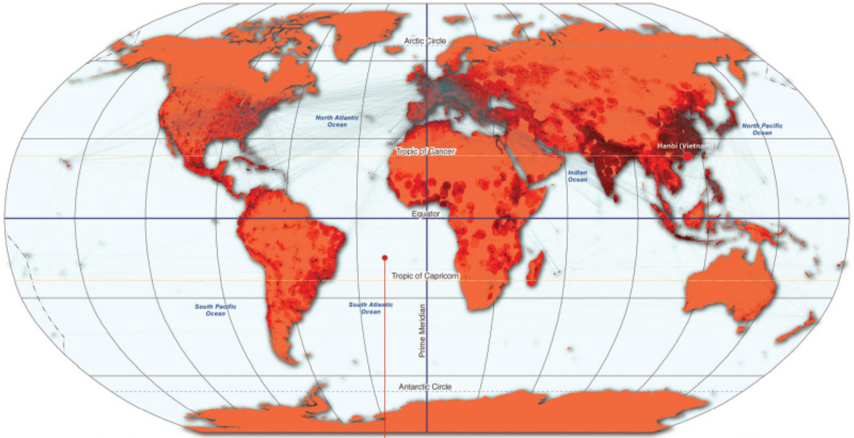
The modeling approach considers infection dynamics (i.e., virus transmission, onset of symptoms, infectiousness, recovery, etc.) among individuals living in urban areas around the world, and assumes that individuals are allowed to travel fom one city to another by means of the airline transportation network.

Numerical simulations provide results for the temporal and geographic evolution of the pandemic influenza in 3,100 urban areas located in 220 different countries. The model allows to study different spreading scenarios, characterized by different initial outbreak conditions, both geographical and seasonal.

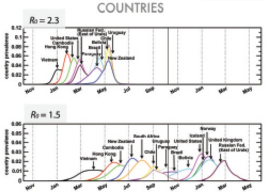
The central map represents the cumulative number of cases in the world after the first year from the start of a pandemic influenza with R_0=1.9 originating in Hanoi (Vietnam) in the Spring.



The US maps focus on the situation in the US after one year, and show the effect of changes in the original scenario analyzed. Different color coding is used for the sake of visualization.



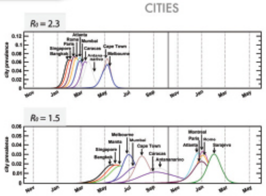
COUNTRIES



R_0=1.5 R_0=1.9 R_0=2.3

Time evolution of a pandemic starting in Hanoi (Vietnam) in the Fall in the no intervention scenario. Profiles of the fraction of infectious individuals in time (prevalence) are shown for some representative countries (left) and cities (right). Two different values of the reproductive number are considered: R_0=1.5, consistently with the values shown for the US map (top right), and R_0=2.3, in order to provide the comparison with faster spreading.

CITIES



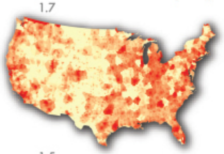
The model inlcudes the worldwide air transportation network (source: IATA) composed of 3,100 airports in 220 countries and E=17,182 direct connections, each of them associated to the corresponding passenger flow. This dataset accounts for 99% of the worldwide traffic and is complemented by the census data of each large metropolitan area served by the corresponding airport.

Additional spreading scenarios can be obtained by modeling different levels of infectiousness of the virus, as expressed in terms of the reproductive number R_0, representing the average number of infections generated by a sick person in a fully susceptible population.

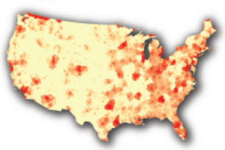
Intervention strategies modeling the use of antiviral drugs can be considered. Two scenarios are compared: an uncooperative strategy in which countries only use their own stockpiles, and a cooperative strategy which envisions a limited worldwide sharing of the resources.

Reproductive Number (R_0)

1.7

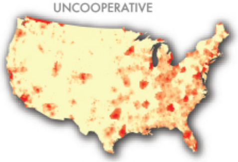


1.5

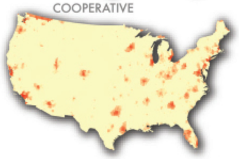


Intervention

UNCOOPERATIVE



COOPERATIVE



Modeling Advantage

Models are widely used in the construction of scientific theories as they help

- Make assumptions explicit
- Describe the structure and dynamics of systems
- Communicate and explain systems
- Suggest possible interventions
- Identify new questions

Computed Using Data from Elsevier's Scopus

Modeling Approaches

- Qualitative and quantitative models
- Deductive, abductive, and inductive models
- Analytic and predictive models
- Universal and domain specific models
- Multi-level (micro-macro) and multi-perspective models

Model Types

- Deterministic models
- Stochastic models
- Epidemic models
- Game-theoretic models
- Network models
- Agent-based models

Computed Using Data from Elsevier's Scopus

Models of Science, Technology, and Innovation

STI models use qualitative and quantitative data about scholars, papers, patents, grants, jobs, news, etc. to describe and predict the probable structure and/or dynamics of STI itself.

They are developed in economics, science policy, social science, scientometrics and bibliometrics, information science, physics, and other domains.

Computed Using Data from Elsevier's Scopus

Maps of Science & Technology

http://scimaps.org

101st Annual Meeting of the Association of American Geographers, Denver, CO.
April 5th - 9th, 2005 (First showing of Places & Spaces)

University of Miami, Miami, FL.
September 4 - December 11, 2014.

Duke University, Durham, NC.
January 12 - April 10, 2015

The David J. Sencer CDC Museum, Atlanta, GA.
January 25 - June 17, 2016.

100 maps and 12 macroscopes by 215 experts on display at 354 venues in 28 countries.

INSTITUTE FOR THE FUTURE

Science & Technology Outlook: 2005–2055

Technology Horizons Program
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A map is a tool for navigating an unknown terrain. In the case of this map, **Science & Technology Outlook: 2005–2055**, the terrain we're navigating is the uncharted territory of science and technology [S&T] in the next 50 years. However, the map of the future is not a tool for prediction or, for that matter, the product of predictions. Nor is it comparable to modern navigation techniques in which we rely on a shrinking number of strong signals, like GPS coordinates, to show the right path. Rather, it's more akin to classical low-tech navigational techniques which we rely on an array of weak signals such as wind direction, the look and feel of the water, and the shape of cloud formations. Taken together, these signals often prove more useful for navigation than high-tech methods because, in addition to aiding travelers in selecting the "right" path, the signals contextualize information and reveal interdependencies and connections between seemingly unrelated events, thus enriching our understanding of the landscape. That's precisely the intention of this map of the future of S&T—to give the reader a deeper contextual understanding of the landscape and to point to the intricacies and interdependencies between trends.

While developing the map, the **Institute for the Future (IFTF)** team listened for and connected a variety of weak signals, including those generated during interviews and workshop conversations involving more than 100 eminent U.K. and U.S. experts in S&T—academicians, policymakers, journalists, and corporate researchers. The IFTF team also compiled a database of outlooks on developments that are likely to impact the full range of S&T disciplines and practice areas over the next 50 years. We also relied on IFTF's 40 years of experience in forecasting S&T developments to create the map and an accompanying set of **S&T Perspectives** that discuss issues emerging on the S&T horizon and are important for organizations, policymakers, and society-at-large to understand.

On this map, six themes are woven together across the 50-year horizon, often resulting in important breakthroughs. These are supported by key technologies, innovations, and discoveries. In addition to the six themes, three meta-themes—democratized innovation, transdisciplinarity, and emergence—will overlay the future S&T landscape influencing how we think about, learn about, and practice science. Finally, S&T trends won't operate in a vacuum. Wider social, demographic, political, economic, and environmental trends will both influence S&T trends and will be influenced by them. Some of these wider trends surround the map to remind us of the larger picture.

MAP THEMES

Small World

After 20 years of basic research and development at the 100-nanometer scale, the importance of nanotechnology as a source of innovations and new capabilities in everything from materials science to medicine is already well-understood. Three trends, however, will define how nanotechnology will unfold, and what impacts it will have. First, nanotechnology is not a single field with a coherent intellectual program; it's an opportunistic hybrid, shaped by a combination of fundamental research questions, promising technical applications, and venture and state capital. Second, nanotechnology is moving away from the original vision of small-scale mechanical engineering—in which assemblers build mechanical systems from individual atoms—toward one in which molecular biology and biochemistry contribute essential tools (such as proteins that build nanowires). Finally, nanotechnology will also serve as a model for transdisciplinary science. It will support both fundamental research and commercially oriented innovation; and it will be conducted not within the boundaries of conventional academic or corporate research departments, but in institutional and social milieux that emphasize heterogeneity.

Intentional Biology

For 3.6 billion years, evolution has governed biology on this planet. But today, Mother Nature has a collaborator. Inexpensive tools to read and rewrite the genetic code of life will bootstrap our ability to manipulate biology from the bottom up. We'll not only genetically re-engineer existing life but actually create new life forms with purpose. Still, we will not be blind to what nature has to teach us. Evolution's elegant engineering at the smallest scales will be a rich source of inspiration as we build the bio-nanotechnology of the next 50 years.

Extended Self

In the next 50 years, we will be faced with broad opportunities to remake our minds and bodies in profoundly different ways. Advances in biotechnology, brain science, information technology, and robotics will result in an array of methods to dramatically alter, enhance, and extend the mental and physical hand that nature has dealt us. Wielding these tools on ourselves, humans will begin to define a variety of different "transhumanist" paths—that is, ways of being and living that extend beyond what we today consider natural for our species. In the very long term, following these paths could someday lead to an evolutionary leap for humanity.

Mathematical World

The ability to process, manipulate, and ultimately understand patterns in enormous amounts of data will allow decoding of previously mysterious processes in everything from biological to social systems. Scientists are learning that at the core of many biological phenomena—reproduction, growth, repair, and others—are computational processes that can be decoded and simulated. Using techniques of combinatorial science to uncover such patterns—whether these are physical, biological, or social—will likely occupy an increasing share of computing cycles in the next 50 years. Such massive computation will also make simulation widespread. Computer simulation will be used not only to help make decisions about large complex scientific and social problems but also to help individuals make better choices in their daily lives.

Sensory Transformation

In the next ten years, physical objects, places, and even human beings themselves will increasingly become embedded with computational devices that can sense, understand, and act upon their environment. They will be able to react to contextual clues about the physical, social, and even emotional state of people and things in their surroundings. As a result, increasing demands will be placed on our visual, auditory, and other sensory abilities. Information previously encoded as text and numbers will be displayed in richer sensory formats—as graphics, pictures, patterns, sounds, smells, and tactile experiences. This enriched sensory environment will coincide with major breakthroughs in our understanding of the brain—in how we process sensory information and connect various sensory functions. Humans will become much more sophisticated in their ability to understand, create, and manage sensory information and ability to perform such tasks will become keys to success.

Lightweight Infrastructure

A confluence of new materials and distributed intelligence is pointing the way toward a new kind of infrastructure that will dramatically reshape the economics of moving people, goods, energy, and information. From the molecular level to the macro-economic level, these new infrastructure designs will emphasize smaller, smarter, more independent components. These components will be organized into more efficient, more flexible, and more secure ways than the capital-intensive networks of the 20th century. These lightweight infrastructures have the potential to boost emerging economies, improve social connectivity, mitigate the environmental impacts of rapid global urbanization, and offer new future paths in energy.

META-THEMES

Democratized Innovation

Before the 20th century, many of the greatest scientific discoveries and technical inventions were made by amateur scientists and independent inventors. In the last 100 years, a professional class of scientists and engineers, supported by universities, industry, and the state, pushed amateurs aside as a creative force. At the national scale, the capital-intensive character of scientific research made world-class research the property of prosperous advanced nations. In the new century, a number of trends and technologies will lower the barriers to participation in science and technology again, both for individuals and for emerging countries. The result with be a renaissance of the serious amateurs, the growth of new scientific and technical centres of excellence in developing countries, and a more global distribution of world-class scientists and technologists.

Transdisciplinarity

In the last two centuries, natural philosophy and natural history fractured into the now-familiar disciplines of physics, chemistry, biology, and so on. The sciences evolved into their current form in response to intellectual and professional opportunities, philanthropic priorities, and economic and state needs. Through most of the 20th century, the growth of the sciences, and academic and career pressures, encouraged ever-greater specialization. In the coming decades, transdisciplinary research will become an imperative. According to Howard Rheingold, a prominent forecaster and author, "transdisciplinarity goes beyond bringing together researchers from different disciplines to work in multidisciplinary teams. It means educating researchers who can speak languages of multiple disciplines—biologists who have understanding of mathematics, mathematicians who understand biology."

Emergence

The phenomenon of self-organizing swarms that generate complex behavior by following simple rules—will likely become an important research area, and an important model for understanding how the natural world works and how artificial worlds can be designed. Emergent phenomena have been observed across a variety of natural phenomena, from physics to biology to sociology. The concept has broad appeal due to the diversity of fields and problems to which it can be applied. It is proving useful for making sense of a very wide range of phenomena. Meanwhile, emergence can be modeled using relatively simple computational tools, although those models often require substantial processing power. More generally, it is a richly suggestive as a way of thinking about designing complex, robust technological systems. Finally, emergence is an accessible and vivid a metaphor for understanding nature. Just as classical physics profited from popular treatments of Newtonian mechanics, so too will scientific study and technical reproductions of emergent phenomena likely draw benefits from the popularization of its underlying concepts.

III.5 *Science & Technology Outlook: 2005-2055* – Marina Gorbis, Jean Hagan, Alex Soojung-Kim Pang, and David Pescovitz - 2006

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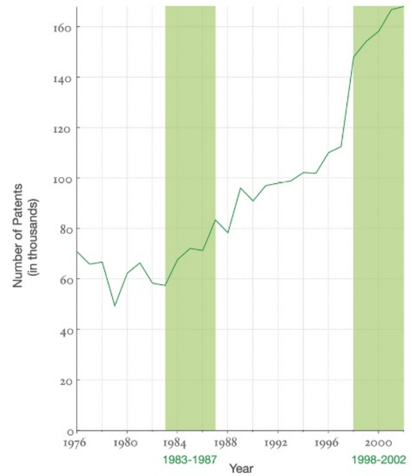
Examining the Evolution & Distribution of Patent Classifications

Managing Growing Patent Portfolios

Organizations, businesses, and individuals rely on patents to protect their intellectual property and business models. As market competition increases, patenting innovation and intellectual property rights becomes ever more important.

Managing the staggering number of patents demands new tools and methodologies. Grouping patents by their classifications offers an ideal resolution for better understanding how intellectual borders are established and change over time.

The charts below show the annual number of patents granted from January 1, 1976 to December 31, 2002 in the United States Patent and Trademark Office (USPTO) patent archive; slow and fast growing patent classes; the top 10 fast growing patent subclasses; and two evolving patent portfolios.



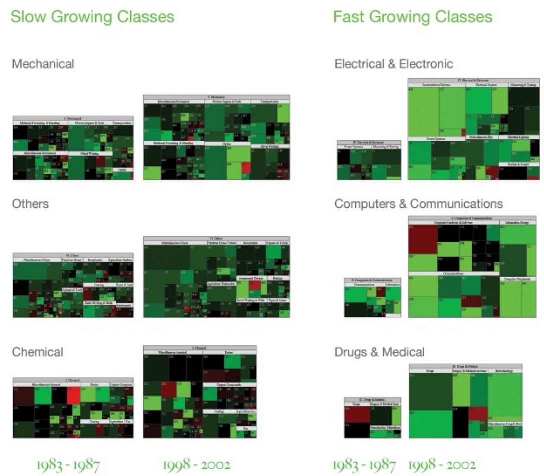
The Structure and Evolution of the Patent Space

The United States Patent and Trademark Office assigns each patent to one of more than 450 classes covering broad application domains. For example, class 514 encompasses all patents dealing with 'Drug, Bio-Affecting and Body Treating Compositions.' Classes are further broken down by subclasses that have hierarchical associations. As one example, class 455 features subclass 99 entitled "with vehicle."

The top 10 fast growing patent classes for 1998–2002 are listed together with the number of patents granted. Most come from the 'Computer and Communications' and the 'Drugs and Medical' area.

The evolving hierarchical structure of patent classes and their sizes is represented using treemaps, a space-filling visualization technique developed by Ben Shneiderman at the University of Maryland. A treemap presents a hierarchy as a collection of nested rectangles—demarcating a parent-child relationship between nodes by nesting the child within the parent rectangle. The size and color of each rectangle represent certain attributes of the nodes.

Here, each rectangle represents a class and the area size denotes the total number of patents in that class. The rectangle's color corresponds to percentage increase (**green**) or decrease (**red**) in the number of patents granted in that class from the previous interval.



Top-10 Subclasses

Class	Title	# of Patents
514	Drug, Bio-Affecting and Body Treating Compositions	18,778
438	Semiconductor Device Manufacturing:Process	17,775
435	Chemistry: Molecular Biology and Microbiology	17,474
424	Drug, Bio-Affecting and Body Treating Compositions	13,637
428	Stock Material or Miscellaneous Articles	13,314
257	Active Solid-State Devices (e.g., Transistors, Solid-State Diodes)	12,924
395	Information Processing System Organization	9,955
345	Computer Graphics Processing, Operator Interface Processing, and Selective Visual Display Systems	9,510
359	Optical: Systems and Elements	9,151
365	Static Information Storage and Retrieval	8,392
	Total	130,910

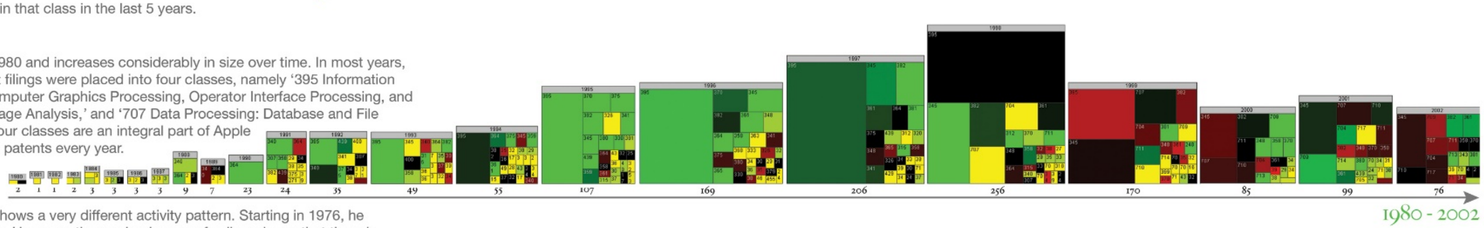
1998 - 2002

Patent Portfolio Analysis

A longitudinal analysis of portfolios reveals different patenting strategies. For each year (given in gray above each treemap), a treemap of all new patents granted to the assignee is shown. The number of patents is given below each treemap. The same size and color coding as above was used. In addition, **yellow** indicates that no patent has been granted in that class in the last 5 years.

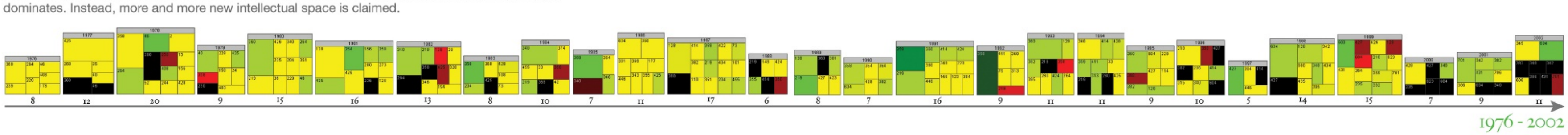
Apple Computer, Inc.

Apple Computer, Inc.'s portfolio starts in 1980 and increases considerably in size over time. In most years, more than half of Apple Computer's patent filings were placed into four classes, namely '395 Information Processing System Organization,' '345 Computer Graphics Processing, Operator Interface Processing, and Selective Visual Display Systems,' '382 Image Analysis,' and '707 Data Processing: Database and File Management or Data Structures.' These four classes are an integral part of Apple Computer, Inc.'s patent portfolio, receiving patents every year.

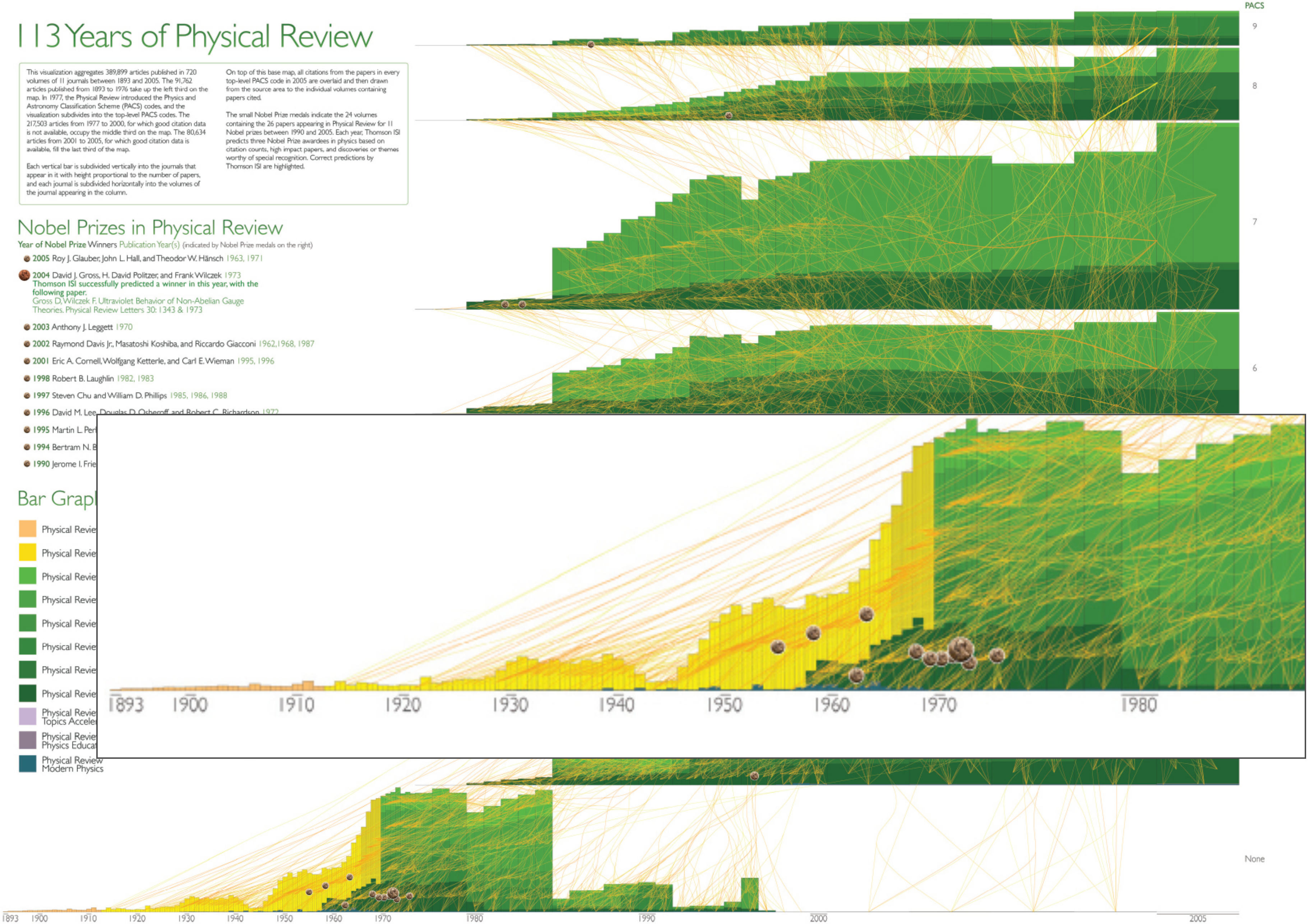


Jerome Lemelson

The patent portfolio of Jerome Lemelson shows a very different activity pattern. Starting in 1976, he publishes between 6–20 patents each year. However, the predominance of yellow shows that there is little continuity from previous years in regards to the classes into which patents are filed. No class dominates. Instead, more and more new intellectual space is claimed.



IV.5 *Examining the Evolution & Distribution of Patent Classifications* - Daniel O. Kutz, Katy Borner, and Elisha F. Hardy - 2004



III.6 *113 Years of Physical Review* - Bruce W. Herr II, Russell J. Duhon, Elisha F. Hardy, Shashikant Penumarthy, and Katy Börner - 2006

WEB OF SCIENCE™ 2016 CITATION LAUREATES

IMPACT OF SCIENTIFIC INNOVATIONS

CHEMISTRY

George Church and Feng Zhang developed application of CRISPR-cas9 gene editing in mouse and human cells.

Dennis Lo Yuk Ming detected cell-free fetal DNA in maternal plasma, a revolution in noninvasive prenatal testing.

Hiroshi Maeda and Yasuhiro Matsumura discovered the enhanced permeability and retention (EPR) effect of macromolecular drugs, a key finding for cancer therapeutics.

PHYSICS

Marvin L. Cohen for theoretical studies of solid materials, prediction of their properties, and especially for the empirical pseudopotential method.

Ronald W.P. Drever, Kip S. Thorne and Rainer Weiss developed the Laser Interferometer Gravitational-Wave Observatory (LIGO) that made possible the detection of gravitational waves.

Celso Grebogi, Edward Ott and James A. Yorke described a control theory of chaotic systems, the OGY method.

MEDICINE

James P. Allison, Jeffrey A. Bluestone and Craig B. Thompson explained how CD28 and CTLA-4 are regulators of T cell activation, modulating immune response.

Gordon J. Freeman, Tasuku Honjo and Arlene H. Sharpe elucidated programmed cell death-1 (PD-1) and its pathway, which has advanced cancer immunotherapy.

Michael N. Hall, David M. Sabatini and Stuart L. Schreiber discovered the growth regulator Target of Rapamycin (TOR) and the mechanistic Target of Rapamycin (mTOR).

Annually, Thomson Reuters analysts mine scientific literature citation data to identify the researchers whose work is worthy of Nobel recognition for induction into the Hall of Citation Laureates. They are the innovators responsible for the world's most influential scientific discoveries, with scholarly papers typically ranking in the top 0.1% by citations within their field. Many go on to win the Nobel Prize for their significant contributions toward the advancement of science.

To learn more visit: **stateofinnovation.com**

Source: Thomson Reuters Web of Science; InCites Essential Indicators. Visit **stateofinnovation.com** to learn more about the 2016 Thomson Reuters Citation Laureates.

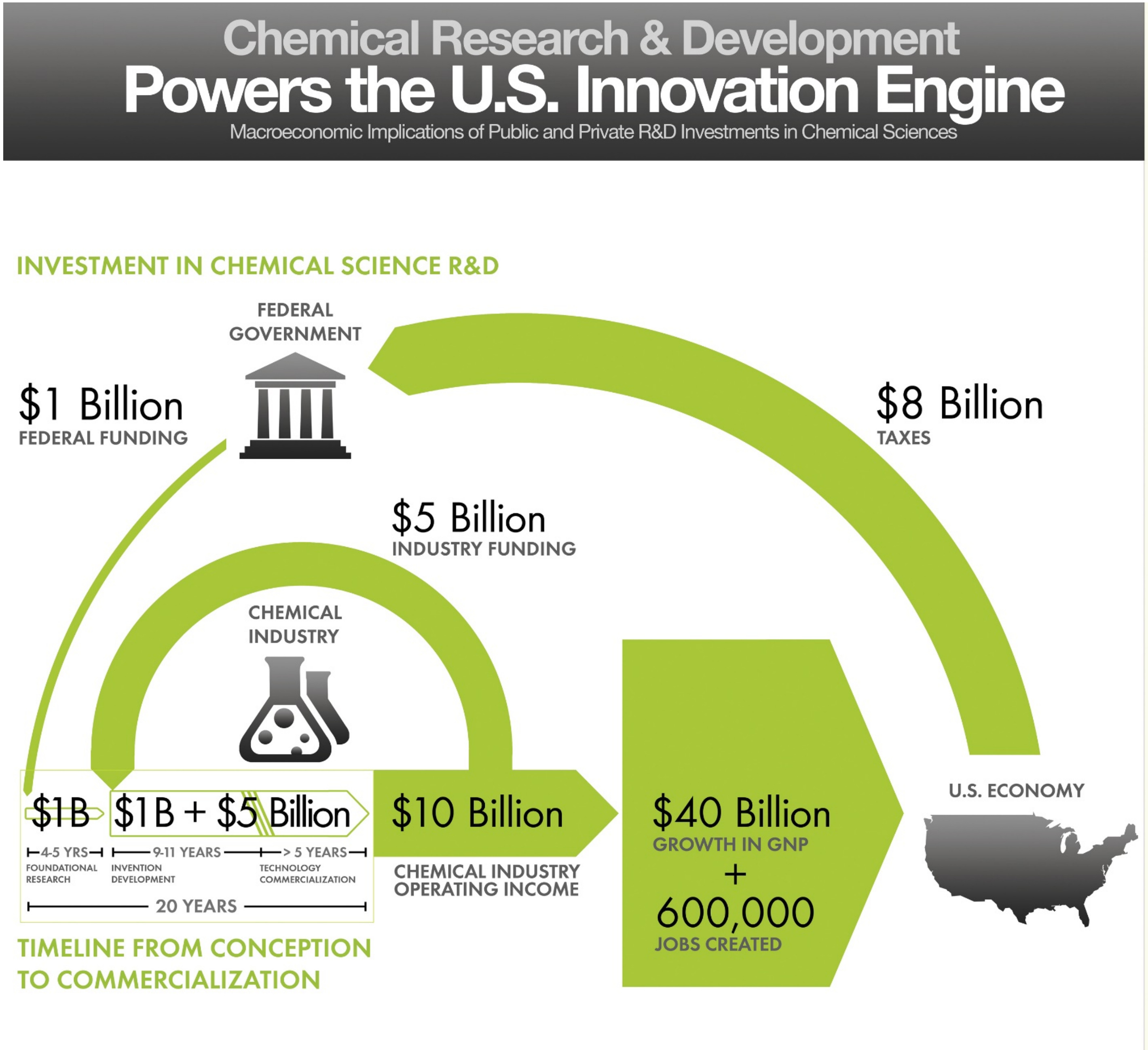
ECONOMICS

Olivier J. Blanchard contributed to macroeconomics, including determinants of economic fluctuations and employment.

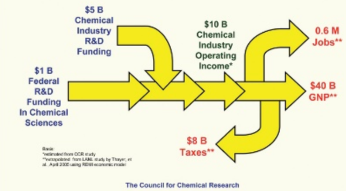
Edward P. Lazear developed the distinctive field of personnel economics.

Mark J. Melitz pioneered descriptions of firm heterogeneity and international trade.

http://stateofinnovation.com/2016-citation-laureates



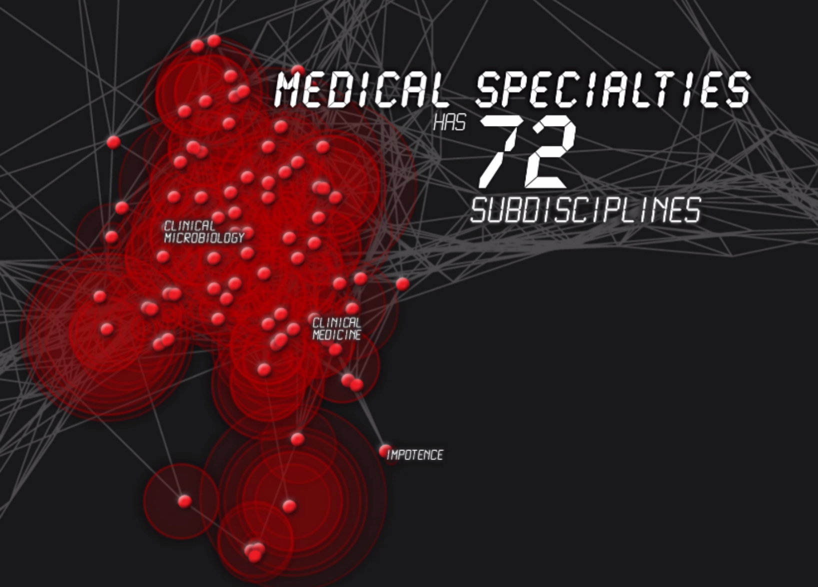
The Council for Chemical Research (CCR) has provided the U.S. Congress and government policy makers with important results regarding the impact of Federal Research & Development (R&D) investments on U.S. innovation and global competitiveness through its commissioned 5-year two phase study. To take full advantage of typically brief access to policy makers, CCR developed the graphic below as a communication tool that distills the complex data produced by these studies in direct, concise, and clear terms.

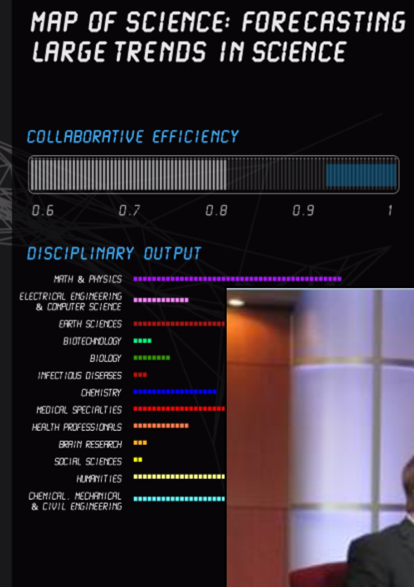


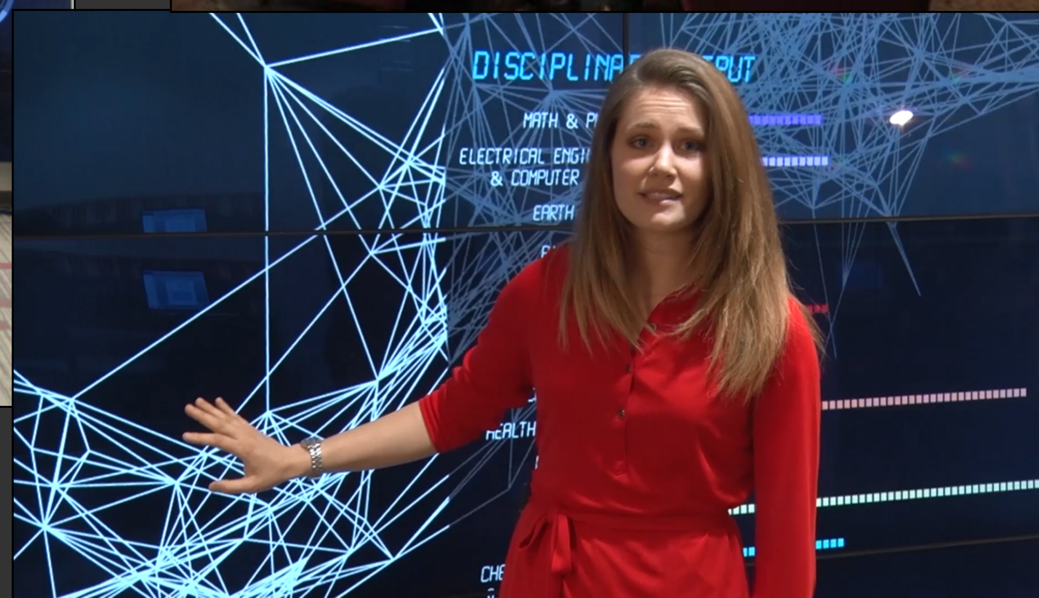
The design shows that an input of $1B in federal investment, leveraged by $5B in industry investment, brings new technologies to market and results in $10B of operating income for the chemical industry, $40B of growth in the Gross National Product (GNP) and further impacts the US economy by generating approximately 600,000 jobs, along with a return of $8B in taxes. Additional details, also reported in the CCR studies, are depicted in the map to the left. This map clearly shows the two R&D investment cycles; the shorter industry investment at the innovation stage to commercialization cycle; and the longer federal investment cycle which begins in basic research and culminates in national economic and job growth along with the increase in tax base that in turn is available for investment in basic research.

V.6 *Chemical R&D Powers the U.S. Innovation Engine* - The Council for Chemical Research - 2009

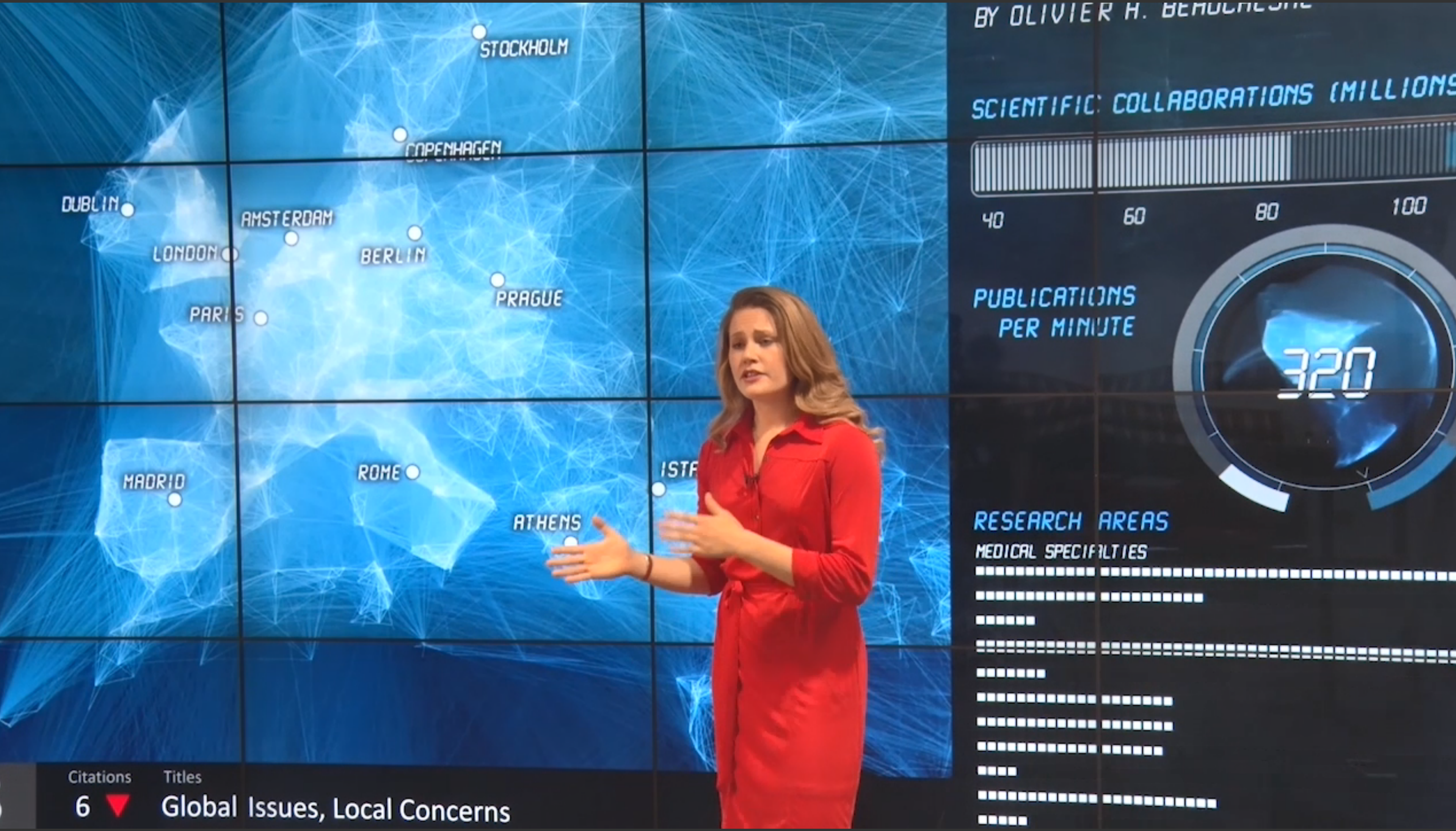
Science Forecast S1:E1



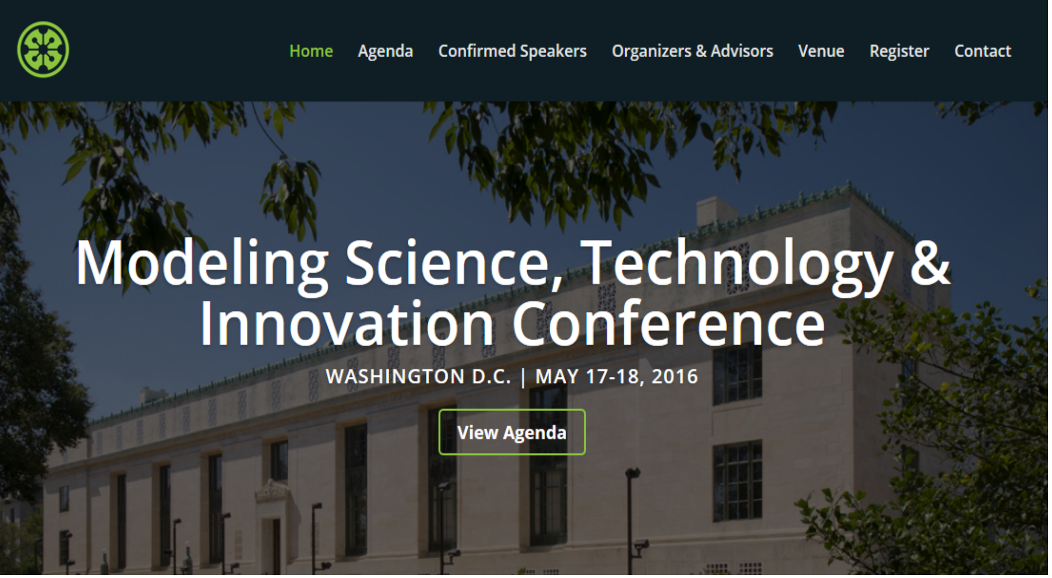




Science Forecast S1:E1



https://www.youtube.com/watch?v=lByX2_eb_QQ



Government, academic, and industry leaders discussed challenges and opportunities associated with using big data, visual analytics, and computational models in STI decision-making.

Conference slides, recordings, and report are available via http://modsti.cns.iu.edu/report

Modelling Challenges

Comprise among others:

- Model utility and usability
- Model credibility and validation
- Model extendibility and reproducibility
- Model sharing and retrieval

Computed Using Data from Elsevier's Scopus

Modelling Opportunities

Now available:

- High-quality, high coverage, interlinked data
- Cost-effective storage and computation
- Validated, scalable algorithms
- Visualization and animations capabilities

#SacklerModVisST

Arthur M. Sackler COLLOQUIA OF THE NATIONAL ACADEMY OF SCIENCES

Modeling and Visualizing Science and Technology Developments

National Academy of Sciences Sackler Colloquium, December 4-5, 2017, Irvine, CA

Rankings and the Efficiency of Institutions

H. Eugene Stanley | Albert-László Barabási | Lada Adamic | Marta González | Kaye Husbands Fealing | Brian Uzzi | John V. Lombardi

Higher Education and the Science & Technology Job Market

Katy Börner | Wendy L. Martinez | Michael Richey | William Rouse | Stasa Milojevic | Rob Rubin | David Krakauer

Innovation Diffusion and Technology Adoption

William Rouse | Donna Cox | Jeff Alstott | Ben Shneiderman | Rahul C. Basole | Scott Stern | Cesar Hidalgo

Modeling Needs, Infrastructures, Standards

Paul Trunfio | Sallie Keller | Andrew L. Russell | Guru Madhavan | Azer Bestavros | Jason Owen-Smith

nasonline.org/Sackler-Visualizing-Science