The 6th International Conference on Foresight

Preliminary Results from Expert Interviews on The 10th Science and Technology Foresight Survey

March 3, 2015

WASHINGTON | CORE

Presentation Outline

Who We Are

WASHINGTON | CORE is a research and consulting company based in Bethesda, Maryland in the US. We offer policy and market analysis in a variety of areas including science and technology (S&T), energy and environment, information and communication technology, telecommunications, media, space, education, intellectual property, manufacturing. The majority of our clients are Japanese government agencies and corporations but we also work with non-Japanese government agencies and international organizations, including APEC and US Small Business Administration (SBA).

For this fiscal year, NISTEP has asked us to conduct interviews with foreign experts on The 10th Science and Technology Foresight, in order to reach out to a community of non-Japanese experts to get involved and to see where there are room to possibly adopt and improve future surveys and processes.

1. Expert Interview Framework

Objectives of Expert Interviews

1) Ask experts who reside outside Japan for comments to see if S&T topics would be applicable to his/her country or globally.

2) Collect information and trends that are relevant to S&T topics, such as S&T policy and strategy, and R&D trends. These include roadmaps, strategic plans, reports on R&D and societal needs.

3) Explore possibilities for future collaborations in foresight surveys.

Research Phases

1) Translated 932 S&T topics used in The 10th S&T Foresight Survey from Japanese to English.

2) Identified scientists and engineers, S&T policy experts, and technology forecasting experts in Europe, the Americas and Asia in eight fields, and then sent interview requests. To those who agreed to talk with us, we sent S&T topics days before the interview.

3) Talked over the phone or met in person to discuss S&T topics and get inputs and comments on S&T topics, as well as on S&T policy and R&D trends in his/her country and in the world. If an interviewee is an expert on technology forecasting, we asked for comments on forecasting in general and suggestions on research methodologies.

Interviewees

Area	Country	Name	Affiliations
ICT and Analysis	US	Michael Nelson	Adjunct Professor, Georgetown University
	US	Dan Siewiorek	Buhl University Professor of Electrical and Computer Engineering and Computer Science, Carnegie Mellon University
Health, medical, and life Sciences	EU	Nathalie Kayadijanian	Senior Scientific Officer for the Medical Scientific Committee, Science Europe
Agriculture, forestry, fisheries, food and biotechnology	US	Sonny Ramaswamy	Director, National Institute of Food and Agriculture, US Department of Agriculture
	US	Miriam Lueck Avery	Program Co-Director, Health Horizons, Global Food Outlook, Institute for the Future
	US	Richard Merrick (Ocean as well)	Director, Office of Fisheries, National Oceanic & Atmospheric Administration
	EU	Elena Kulikova	(former) Strategic Policy and Foresight Unit, European Forestry Institute

Interviewees (cont.)

Area	Country	Name	Affiliations
Space, ocean, earth and science infrastructure	US	Scott Pace	Director, Space Policy Institute, The George Washington University
	US	Alexander "Sandy" McDonald	Chief Science Advisor, Office of Oceanic and Atmospheric Research, National Oceanic & Atmospheric Administration
Environment, resource and energy	US	Alex King (Material as well)	Director, Critical Materials Institute, Ames Laboratory
	UK	Jim Watson (Material as well)	Research Director, UK Energy Research Centre
Material, device, and process	PT	Rodrigo Martins	Former President, European Materials Research Society; Faculty of science and Technology, New University of Lisbon
Social Infrastructure	US	Edward Derrick	Chief Program Director, Center of Science Policy, and Society Programs, American Association for the Advancement of Science (AAAS)
Service-oriented society	UK	Tim Baines	Aston Centre for Servitization Research and Practice, Aston Business School

Interviewees (cont.)

Area	Country	Name	Affiliations
Forecasting in general	US	Charles Twardy	C4I Center, George Mason University
	US	Avery Sen	Senior Analyst, Office of Policy, Planning and Evaluation, National Oceanic & Atmospheric Administration
	US	William Halal	Professor Emeritus of Management, Technology, and Innovation, George Washington University
	US	Nicholas Vonortas	Professor, Center for International Science and Technology Policy, George Washington University

Interview Questions (examples)

<S&T Topics/Trends>

- Do you think S&T topics are appropriate considering the current trends in society and S&T in your country and worldwide?
- Are there any other S&T topics you think we need to add when it comes to your country or worldwide?
- Do you think of any technology trends or societal needs that need to be considered or taken into account in a future foresight survey in your country and worldwide?

<Policy>

- Do you know any policies or roadmaps in your country that address some (or all) of the S&T topics? Do you see any relevance between the topics and policies/roadmaps?

Interview Questions (examples) (cont.)

<Foresight Study>

- Have you ever participated in foresight surveys such as this before? If so, who did it and which methodologies were employed? Did you find the finding useful?
- Do you know any foresight surveys going on or being done in your field? Do you think foresight surveys are needed in your community?
- What kinds of methodologies do you think are appropriate for foresight study in your field?
- Is there anything we need to be aware of when conducting a foresight study?
- Do you know anyone or any organization who is doing foresight studies in your field?

<Possibility for a Future Collaboration>

- Do you know any organizations or experts in your country or globally who will be interested in participating in a foresight survey in the future?
- What would be an effective way in your country to reach out to hundreds/thousands of experts to ask them to participate in a foresight survey?

2. Foresight Practices in the US

Forecasting in the US

- Foresight/forecasting was popular in the 1970s, but it has generally become unpopular in the recent years. There are resistances against forecasting methodologies partly because:
  - Political pressure – Policymakers often do not use foresight results when formulating budget and plans. They are reluctant to pick “winners”.
  - Innovation – Innovation often cannot be facilitated by policy. Radical innovation and technology breakthroughs cannot be planned.

- Scientific and engineering community considers that annual meetings, periodical meetings and workshops (such as National Academy of Engineering annual meeting) provide great opportunities to get and discuss new ideas. These work as a drive for advancing capabilities in getting people to think about what’s new.

- However, we see some interesting forecasting projects happening in the US, mostly at the grassroots level.
  - SciCast by George Mason University
  - TechCast Global by Dr. William Halal

SciCast Overview

- Launched in November 2013. Originally started as Europe-based geopolitical forecasting, and later split into two groups – geopoliticis forecasting and S&T forecasting (SciCast).

- SciCast is “the largest and most advanced science and technology prediction market in the world”, and is “a community-driven initiative that allows scientists, technologists, and technology watchers around the globe to forecast science and technology trends, and to contribute forecasting questions.” SciCast is “a real-time indicator of what participants think is going to happen in the future.”

- Goals:
  - to make accurate well-documented forecast
  - to push the boundary of the combinatorial market (new technology).

Source: C. Twardy, R. Hanson, K. Laskey, T. Levitt, B. Goldfedder, A. Siegel, B. D’Ambrosio, D. Maxwell “SciCast: Collective Forecasting of Innovation,” *Collective Intelligence*, 2014.

SciCast Overview (cont.)

- Process:
  - Participants propose questions.
  - Participants can move probabilities of a question up or down in accordance with their beliefs. They can update their estimates at any time.
  - When the answer becomes known, participants will win or lose points according to whether they moved the probability in the right direction.
  - Participants can engage in discussions of future technological trends on the discussion board.

- Currently there are 560 open questions.

- After the answer to a question is known and made public, participants who answered correctly will be rewarded and move up on the leaderboard. The more correct forecasts a participant makes, the more influence they'll have in other forecasts, and those moved it in the wrong direction have fewer point and less influence in the market.

Source: C. Twardy, R. Hanson, K. Laskey, T. Levitt, B. Goldfedder, A. Siegel, B. D'Ambrosio, D. Maxwell "SciCast: Collective Forecasting of Innovation," *Collective Intelligence*, 2014.

SciCast Overview (cont.)

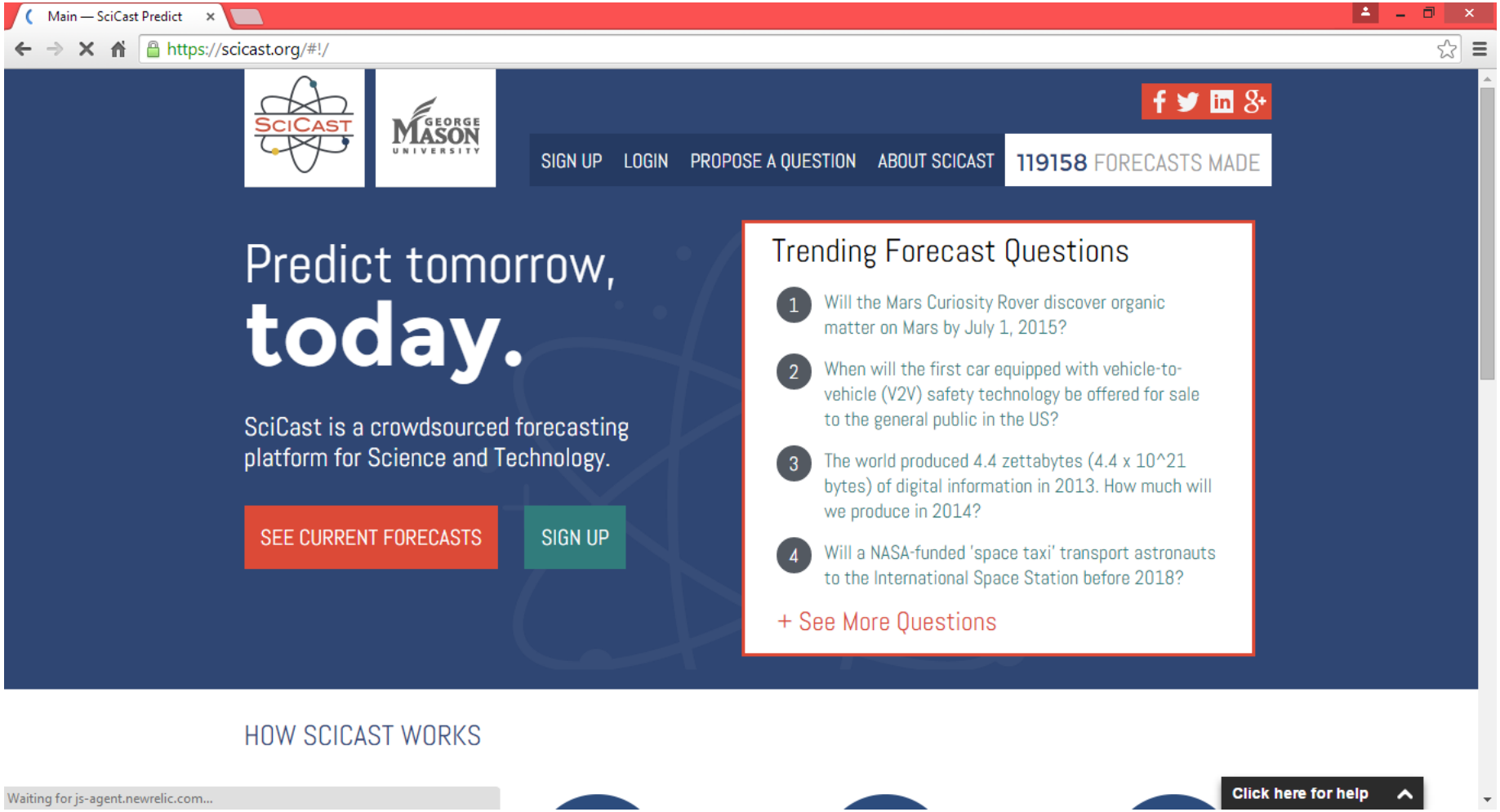
- SciCast topics include: agriculture, biology and medicine, chemistry, computational sciences, energy, engineered technologies, global change, information systems, mathematics, physics, science and technology business, social sciences, space sciences and transportation.

- Users can be as anonymous as they want it to be. Some users use Twiter handles for log-in names. However, through Good Judgment, project users are asked to take psychometric tests periodically so that SciCast understands the user demographic (newly-retired, followed by 20-something scientists and engineers).

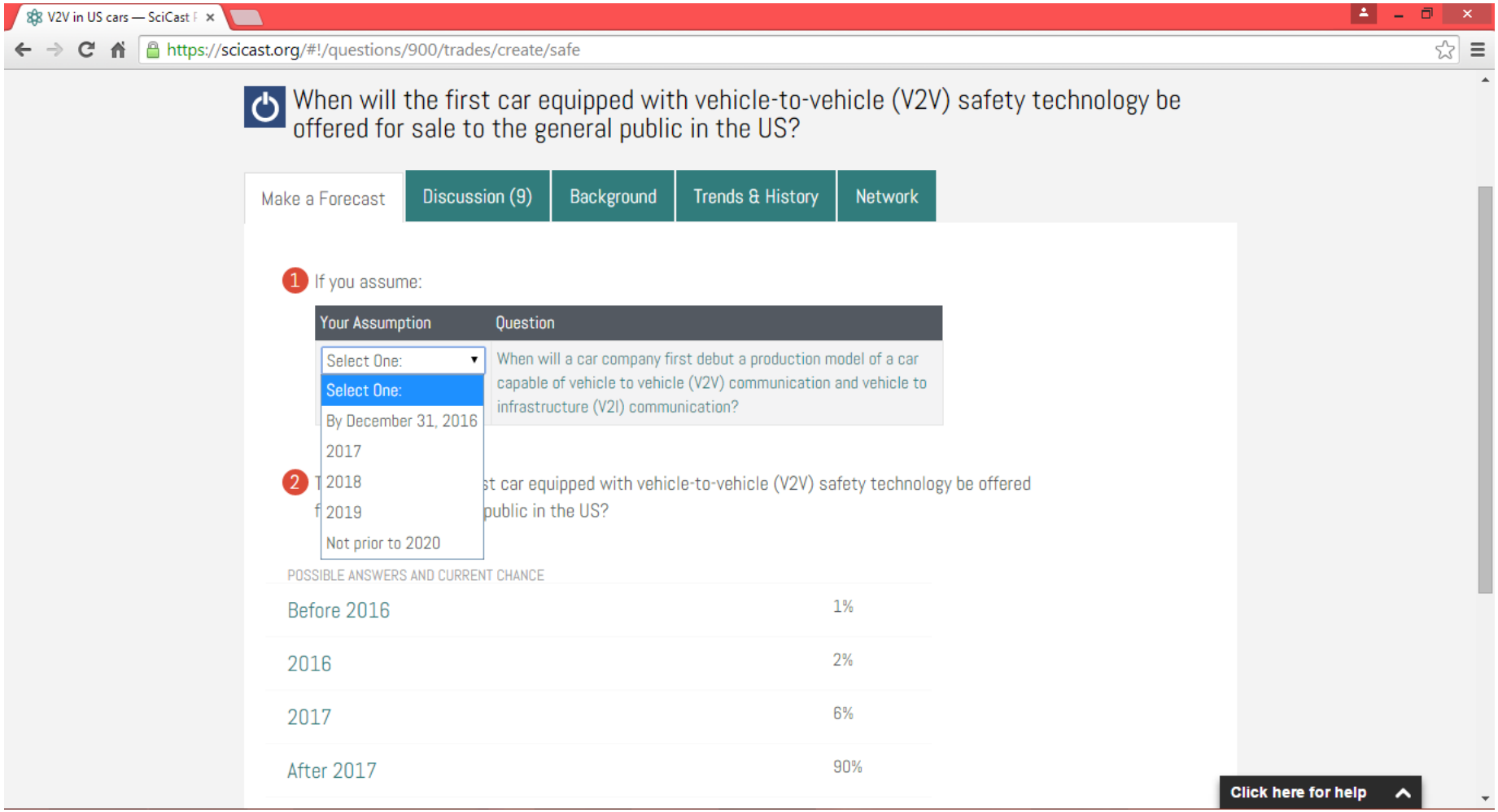
- Partner: AAAS, IEEE, ISACA, ACS (American Chemical Society), AMIA (American Medical Informatics Association), ICE (Institution of Civil Engineers), etc.

Source: https://scicast.org/; C. Twardy, R. Hanson, K. Laskey, T. Levitt, B. Goldfedder, A. Siegel, B. D'Ambrosio, D. Maxwell "SciCast: Collective Forecasting of Innovation," *Collective Intelligence*, 2014.

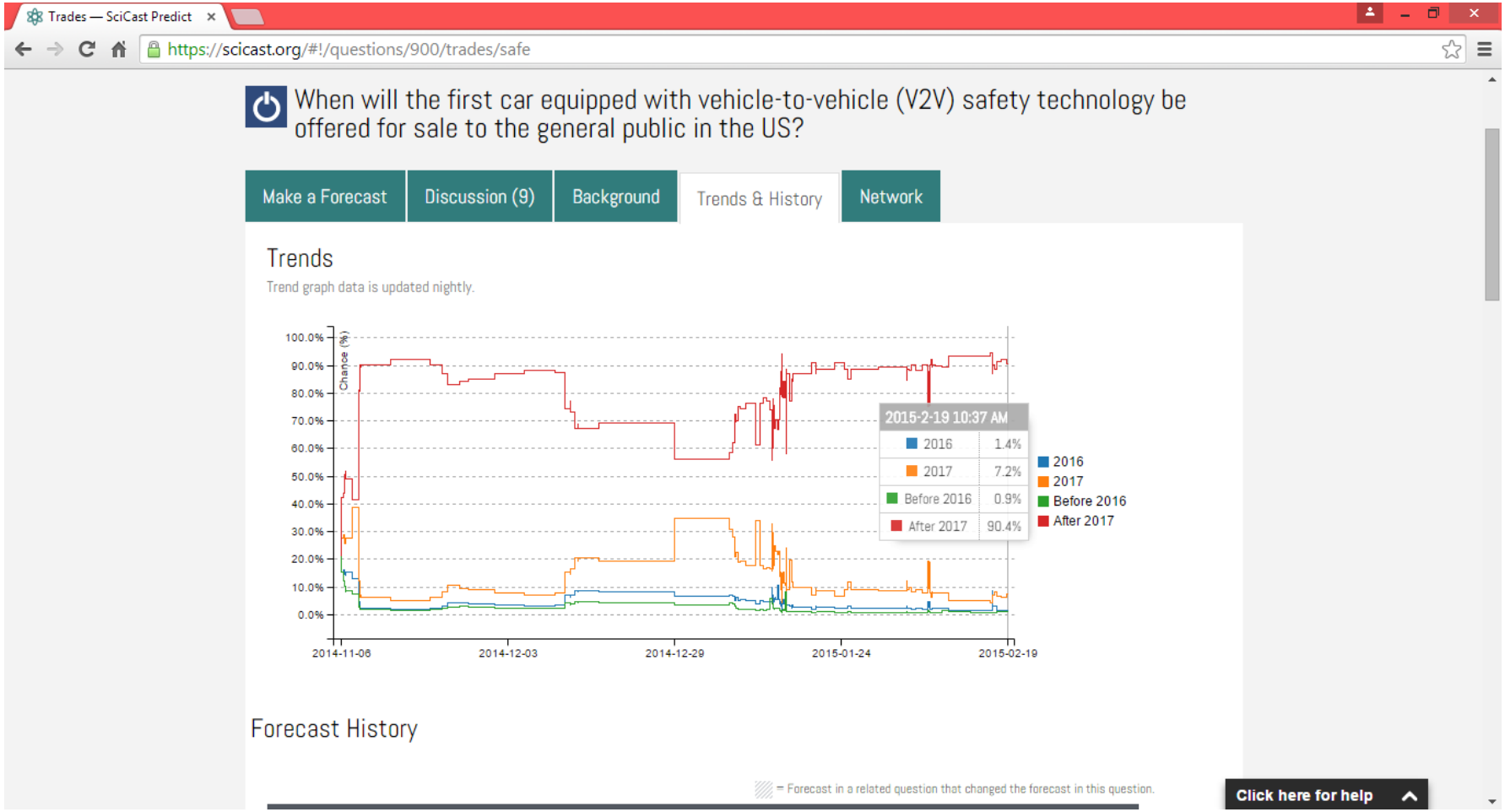
SciCast Homepage



SciCast Forecast Quesion



Real-time Forecasting via SciCast



TechCast Global

- Developed by Professor William Halal at George Washington University almost 20 years ago. Started as a simple Delphi survey.

- They look at 60 Emerging Technologies (technology breakthroughs), 3 Social Trends (economic, political and social changes), and 20 Wild Cards (low probability/high impact events that could alter assumptions about the future).

- Technology Forecasts are made based on empirical background data organized into Pro and Con trends (through scanning existing publications and data), supported by examples of R&D projects, new ventures, and other applications, and the TechCast Expert Panel of about 100 scientists, engineers, scholars, consultants, and futurists provide forecasts of the most likely year to reach adoption levels, potential market size, and expert confidence. (collective intelligence)

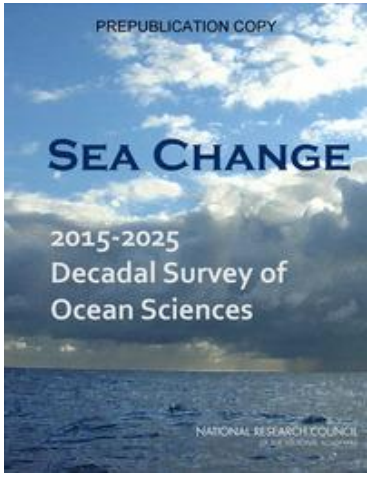
TechCast Global (cont.)

- Their forecasting system is evidence-based and considered one of the best in the world.
- No time horizons and the most distant technology covered as of now is interstellar travel (2050-2060 timeframe).
- Forecasts, research reports, articles, blogs, and other resources are provided to subscribers.
- Experts can apply online to become part of TechCast Expert Panel. Also TechCast recruits qualified experts.

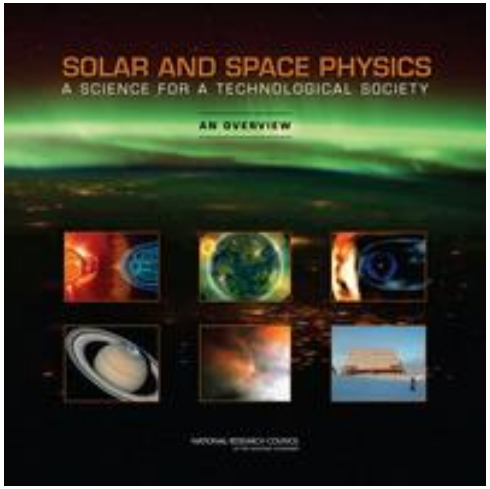
Alternatives to Foresight

There are several interesting efforts going on within government agencies.

- Decadal Surveys by National Academies
  - Used in space/aeronautics/earth sciences
  - Present research priorities for the next 10 years.
  - Developed by expert panels, with an input from the community through concept papers, town hall meetings.
  - Lawmakers or agencies are not required to follow the recommendations but this publication is highly regarded.

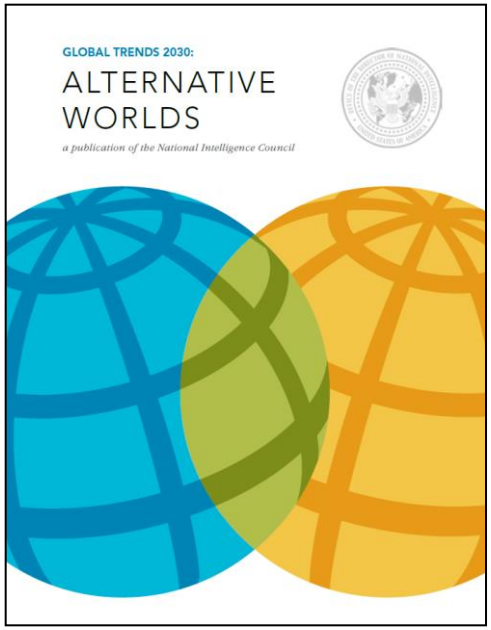


- Quadrennial Energy Review (QER) by Department of Energy
  - Year 1 (2014): Transmission, storage & distribution; Year 2: Supply/end use infrastructure; Year 3 & 4: TBD
  - Baseline, systems and scenario analysis; System and policy options analysis; Policy analysis; policy recommendations



Alternatives to Foresight (cont.)

- Global Trends by National Intelligence Council (NIC)
  - The first report was released in 1997 and a new report is published every 4 years following the US presidential election.
  - Various methodologies are used, including workshops, International Futures model, gaming exercises. Not only hosting events at US universities, visits to China and African countries were organized.
  - The report does “not seek to predict the future” but instead provides “a framework for thinking about possible futures and their implications”.
  - Most recent report is “Global Trends 2030: Alternative Worlds” (December 2012)

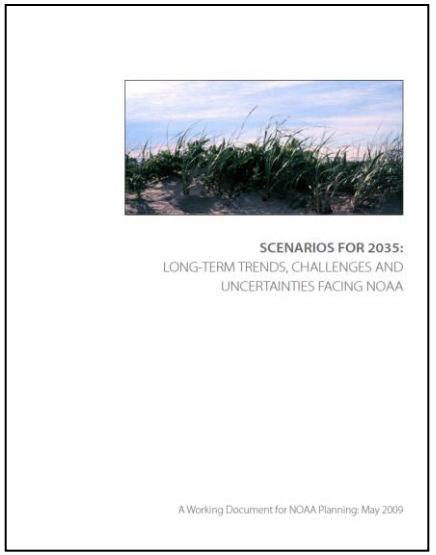


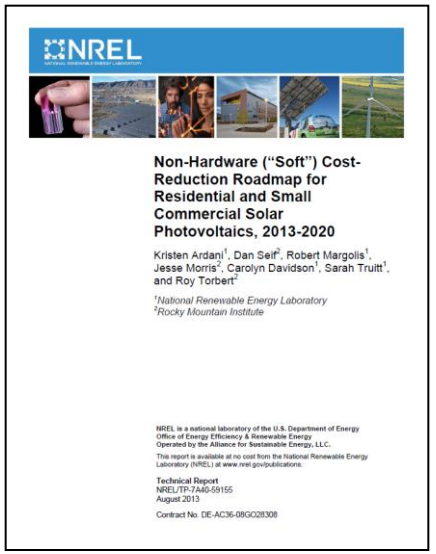
Source: National Intelligence Council, “Global Trends 2030: Alternative Worlds” http://www.dni.gov/files/documents/GlobalTrends_2030.pdf

Alternatives to Foresight (cont.)

- Scenario writing
  - Usually done as part of policy strategic planning
  - NOAA “Scenarios for 2035: Long-term Trends, Challenging and Uncertainties Facing NOAA” (May 2009). Based on expert opinions.

- Roadmaps
  - At the government level, roadmaps are usually done for specific goals within the agencies.
  - For example, Department of Energy’s National Renewable Energy Laboratory “Non-Hardware Cost Reduction Roadmap for Residential and Small Commercial Solar Photovoltaics 2013-2020” (August 2013). Charting a path to achieve soft-cost targets of $0.65/W for residential systems and $0.44/W for commercial systems by 2020.
  - Also many industry associations use roadmaps – including Semiconductor Industry Association’s annual “International Technology Roadmaps for Semiconductors”.





3. Expert Interview Results

S&T Topics: Aligned with R&D Trends

Experts agree that most of S&T topics are relevant and aligned with what researchers are working on in their countries and globally.

<Agriculture, forestry, fisheries, food and biotechnology>

- *Development of super trees by employing a high-speed breeding technology which uses the genomic information of trees such as Japanese cedar and hinoki cypress*.
- *Creation of non-invasive acoustic measurement technology and a voice recognition database for fish and marine mammals.*
- *Fish farming using plant material to reduce environmental impacts*.

<Space, ocean, earth and science infrastructure>

- *A system to achieve access to space at a low cost (i.e. reusable transportation systems, service technologies for satellites such as fueling, maintenance, and replacement of equipment, etc.).*
- *Observation technology to verify the cosmic inflation hypothesis.*
- *Technology to detect dark matter particles based on the hypothesis that dark matter is an unknown type of particle.*

<Material, device, and process>

- Additive manufacturing

S&T Topics: Japan-specific Contexts

Some are unique to Japan and do not apply to their countries or globally.

<Agriculture, forestry, fisheries, food and biotechnology>

- *Advanced utilization technology that relies on a biorefinery to take advantage of the properties of bamboo (for fiber materials, building materials, etc.)*.
- *Efficient capture and distribution technology which prevents damage caused by wild animals by managing their populations while utilizing their meat for consumption*.
- *Technology to remove radioactive substances in order to revitalize fishing in coastal areas*.

<Environment, resource and energy>

- *10MW-class offshore floating wind power generation.*

<Material, device, and process>

- *A system to facilitate the inheritance of skills from artisans (skilled workers, craftsmen, etc.) through the measurement and modeling of such skills and the archiving of the implicit knowledge involved.*

S&T Topics: Not Noble Concepts

Some (or similar technologies) have been already been commercialized or put in use.

<Agriculture, forestry, fisheries, food and biotechnology>

- *A gasification power generator that utilizes waste and unused biomass.*
- *Technology to predict the variation in sardines, tuna, and other major fishery resources under different harvesting and long-term environmental conditions, as well as technology for the proper management of fishery resources based on this prediction technology*.

<Space, ocean, earth and science infrastructure>

- *A 24-hour high precision homeland monitoring system based on satellites to ensure public safety and security and provide data for industrial use.*
- *A highly accurate and precise positioning technology based on satellites that provides accurate position information in real-time with an error range of only a few centimeters in order to improve the productivity of unmanned or automated agricultural production and management (including improvement of atomic clocks).*
- *A real-time oceanic condition monitoring system to track sea ice, ocean surface temperature, waves, ocean currents, and chlorophyll globally via satellites for use in the fisheries industry.*

<Environment, resource and energy>

- *Sorting sensor technology for improved refuse sorting and separation systems*.

S&T Topics: Leading Countries

Some experts pointed out that we should look at other countries' advanced examples.

<Agriculture, forestry, fisheries, food and biotechnology>

- In Finland, companies like Stora Enso are starting to work on new types of materials such as textiles and mixed plastics based on wood and biomass. Tetra Pak is demonstrating the ability to create things like bioplastic. Finland might be a good place to look regarding new types of materials based on wood and biomass.
- PlantLab in the Netherlands that pursues radical innovations in plants that can grown indoors at any scale with the right combination of lighting, air flow and circulation.
- Norway has one of the most advanced countries in fish finding technology and applications. Japan had cutting edge satellite-based telemetry technology but that disappeared.

S&T Topics: Technological Feasibility

Some are too complex, too ambitious, and/or too far away from solutions.

<Space, ocean, earth and science infrastructure>

- *Observation technology to clarify the identity of dark energy.*
- *Technology to directly observe gravitational waves.*
- *Technology to constantly observe the land and coastal areas of East Asia, Southeast Asia, and Australia at a spatial resolution of 30 meters using geostationary satellites to support risk management related to food, water, and disasters in those regions.*
- *Highly accurate automatic measuring technology for the measurement of water temperature, salinity, dissolved oxygen, nutrient salts, and total carbonic acid from the ocean surface to the ocean floor at a grid interval of 30 kilometers.*

<Environment, resource and energy>

- *Technology for recovering helium effectively from the air.*
- *Fast breeder reactor (FBR) system technology, including the entire nuclear fuel cycle and integral fast reactor (IFR).*

<Material, device, and process>

- *Practical power semiconductors for electrical use which have lower losses than silicon carbide (SiC) or gallium nitride (GaN).*

S&T Topics: Other Concerns

Some are more policy and/or money issues, not technology.

<Space, ocean, earth and science infrastructure>

- *Construction of a permanent manned operating base on an extraterrestrial body (i.e. the Moon or Mars) for the purpose of scientific observation, resource use, etc.*

<Material, device, and process>

- *A fab system which is capable of producing a large variety of semiconductor devices or integrated circuit chips in small production volumes on-demand within a short period of time.*
- *Refining technologies with a reduced ecological footprint through the construction of new manufacturing systems such as direct reduction, etc.*

Some have business model problem (technology is interesting, but it's not clear who pays for the service)

<Space, ocean, earth and science infrastructure>

- *Technology to predict the local occurrence of heavy rain, tornadoes, hail storms, lightning strikes, and snow which will occur several hours in the future at a spatial resolution of less than 100m using a high-resolution simulation and data assimilation.*

<Environment, resource and energy>

- The list does not make clear how these technologies apply to industry.

S&T Topics: Other Concerns (cont.)

Some have security and privacy concerns.

<ICT and analytics>

- *A system which analyzes data from social media sites and predicts human behavior*

Some might cause resistance from society.

<Agriculture, forestry, fisheries, food and biotechnology>

- *Development of super trees by employing a high-speed breeding technology which uses the genomic information of trees such as Japanese cedar and hinoki cypress.*

Some have other implications/applications.

<Agriculture, forestry, fisheries, food and biotechnology>

- *An understanding of the regional genetic divisions between populations of major tree species used in commerce based on molecular markers for the analysis of regional differentiation and genetic diversity.* This can be used to eliminate illegal logging and trade of illegally-logged timber, by enabling the identification of the region of origin of lumber.

S&T Topics that might be of Interest

<ICT and analytics>

- Technologies similar to Microsoft NUI (Natural User Interface) with advanced level of facial and voice recognition. Interacting with information system, data and keyboard opens up to a new idea of applications and opportunity.
- Security-related technologies. 1) Technologies that ensure that law enforcement and governments can monitor people's behavior online for criminal activities while the desire of companies and people o maintain their privacy is not compromised. 2) Encryption technology.

<Health, medical, and life Sciences>

- Infectious diseases, neglected diseases, emerging and reemerging diseases, and management at the international level. E.g., Ebola needs to be addressed in the future.
- How to modify the genes themselves.
- Big data is a disruptive innovation in biomedical research and enables personalized medical care. We are moving toward a data-driven kind of science and it will revolutionize the whole medial field. At the same time, we need a framework for and to regulate big data.
- Rare disease research (including gene therapy)

S&T Topics that might be of Interest (cont.)

<Agriculture, forestry, fisheries, food and biotechnology>

- Forest plantations, where trees are grown like other agricultural products for harvesting.
- Protected areas (areas to protect losses in biodiversity) under environmental protection. Also protection of species that are under threat of extinction.
- Video image recognition for both fish and marine mammals. Application will be cameras on ships to see what they are discarding and count discards.
- Combining biologic and environmental models for fisheries. Using more complex, multiple models to get more accurate prediction.
- Modeling management systems and alternatives to deal with the uncertainty in the modeling and in management for fisheries.
- Genomics for marine resource conservation.
- Coastal community impact assessment and management strategies. Consider human ecosystem.
- Aquaculture and balance of trade. 70-80% of fish in the US are imported and the US is trying to reduce that by improving the aquaculture community's ability to produce fish.
- New ways for ocean sensing including unmanned aircraft, etc.
- The intersection of food and health, such as microbes.

S&T Topics that might be of Interest (cont.)

<Space, ocean, earth and science infrastructure>

- Solid earth science (as opposed to polar ice coverage issues that have been getting more attention because of climate change)
- Space biomedical or life sciences research.
- Prepare for catastrophic geo-physical events (a large volcanic explosion or a tsunami) that impact temperatures, agriculture, and people's lives. It's hard to predict when the event occurs so contingency is more important. Also consider "what if methane is released?"

<Environment, resource and energy>

- Carbon capture storage (CCS)

<Material, device, and process>

- Technologies that enable reuse and recycle (circular economy).
- 3D printing, notably for health and electronics.
- Low-cost technologies, including printing and nano.

<Social Infrastructure>

- Geoengineering
- Use of big data (information assistance and gathering for disaster management)

Suggestions for Future Surveys

- Address how technology interacts with people (more social science side needed). Understanding about how organizations and people embracing new technologies is necessary.
  - How technology affects society, and how society affects technology?
  - Look for the comfort of the citizens.
  - Connection to human sciences, such as behavioral research. Take into account how people will adopt them, why they do, and why they don't, etc.

- Not only focus on the technical problems, look at the breakdown between technical, economic, and policy problems.
  - Oftentimes, policy and market decide what technologies are needed (e.g., critical materials and energy).
  - Relate to S&T plans and policies. (e.g., How does any of S&T topic in space related to the new Japanese Space Basic Plan?)

- Think about cost and research needs to be for practical ends.

- Need more consistency among topics. Some topics are too broad or open-ended, while others are too specific. (more open-ended statement is better than too specific, if the purpose is to make scientists think of solutions and next research/funding ideas). Try to be as specific as possible in what way you are specific (technology? outcome?)

Suggestions for Future Surveys (cont.)

- Many S&T topics fall into ICT (In case of Service-oriented society, Service Sensing – using/analyzing/transferring data).

- Convene conversations in North America, Africa, Asia, Europe, poor/rich countries, and take out any specific-country-centric focus. Do not do it one time. Open it up to laypeople (consumers) not only to scientists.

- Forecasting ICT is pretty challenging and we'll miss 20 to 30 percent, sometime its most important 20 to 30 percent. It's fairly easy to predict technology trends and falling cost of storage, but where it gets tricky is when you think about how will those new applications be used and how they will disrupt the industries, societies, lives and even politics. You can't prepare for one future. It's really about being ready for couples of different outcomes.

- After foresight study is done, we need a cool product that can engage people. For example, hire web designers and have them cool interactive website. Incorporate the arts and humanities into foresight products.

4. Conclusions

Conclusions

- Most of the experts are very positive about the NISTEP Foresight Survey and agree that S&T topics make sense and are align with the general trend of technology development and the society.
- Scientists and engineers rely on conferences and workshops to get information on what's going on in the field.
- Foresight activities are minimal especially in the US, however there are quite a lot of grass-roots activities happening right now.
- Themes that repeatedly came up in the interviews are big data, human behavior, cost, and extreme events (natural and human-made disasters including climate change).

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