POLICYMAKER RECOMMENDATIONS

1. Govern with foresight. Many scholars have called for increased use of foresight in the United States government (Coates 1985; Fuerth 2012) and this research underscores that need. A government wide office run through the Executive Office of the President could facilitate foresight thinking across all agencies. The United Kingdom's Foresight Projects coordinated through the Government Office for Science (United Kingdom Government Office for Science 2013) is a successful example in another developed country. Their office handles projects such as the future of aging (United Kingdom Government Office for Science 2014) or the future of cities (United Kingdom Government Office for Science 2015) and claims successes such as foresight reports on climate change, land use, and reducing obesity twenty to eight years from now (United Kingdom Government Office for Science 2013). In fact, European foresight programs have been so successful that the European Union institutions are now building a joint foresight capacity—the European Strategy and Policy Analysis System (ESPAS) to assess long term global trends in order to improve policy planning (Dreyer and Stang 2013).

2. Encourage systematic consideration of emerging and converging technologies. One of the most interesting findings of this research is that the gap between current and potential use of emerging and converging technologies is partially caused by the fact that new technologies are considered incrementally, if at all. This research demonstrates the feasibility of systematically applying strategy and foresight to connect emerging and converging technologies with the agency strategies they can help fulfill.

3. Support methodologies that connect current and potential use of emerging and converging technologies with agency strategies. Despite tools like STAR METRICS™ (National Institutes of Health 2015), data.gov (United States Government 2015), Google's Public Data Explorer (Google 2015), and agency strategic plans, there are gaps in our nation's data and strategies. This is certainly true about federal agency use of technology in general and emerging and converging technologies in particular. A methodology such as the one developed and proposed here fills those gaps with systematic information about current and potential uses of emerging and converging technologies and characterizes the uses by agency strategy, technical feasibility, and priority for investment.

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"…invest in the emerging technologies that will create high-quality manufacturing jobs and enhance our global competitiveness"

EXECUTIVE OFFICE OF THE PRESIDENT 2014

"Gouverner, c'est prévoir," "to govern is to foresee," French politician Pierre Mendès"

GOUVERNER C'EST PRÉVOIR, DISCOURSE D'INVESTITURE ET RÉPONSES AUX INTERPELLATEURS 1953

THE FORESIGHT CHALLENGE

What are the current and potential uses of emerging and converging technologies for fulfilling agency strategies?

EXECUTIVE SUMMARY

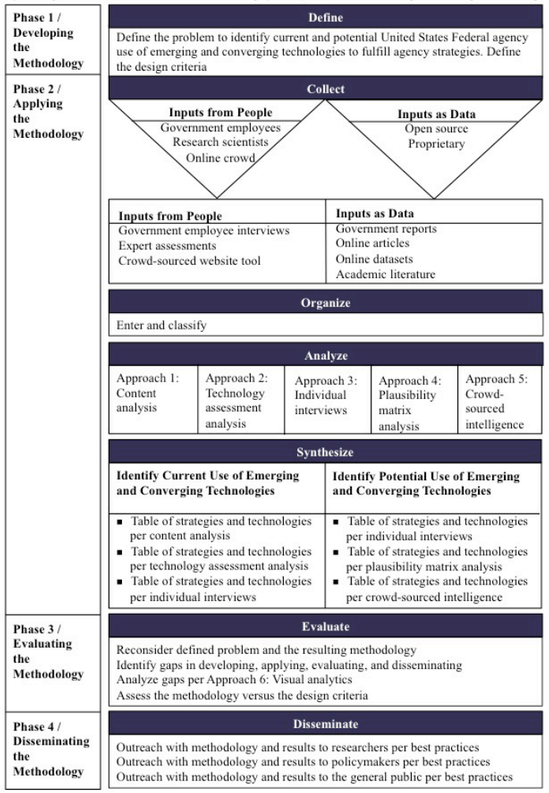
This research develops a methodology to characterize current and potential United States federal agency use of emerging and converging technologies to fulfill agency strategies and serve society. Although some methodologies exist for systematic and strategic consideration of emerging and converging technologies, they typically do not incorporate agency current and potential use by agency strategies.

Key findings, results, and meta-inferences of this research are that there are many potential uses for using emerging and converging technologies to fulfill agency strategies; the research also identifies some of the potential uses by agency strategy. These potential uses are presented in terms of comparable technical feasibility and societal benefit. Implications for policymakers are that governing with foresight is critical; encouraging systematic agency consideration of emerging and converging technologies is necessary; and thus it is important to implement a government-wide methodology that will characterize current and potential use of emerging and converging technologies for fulfilling agency strategies. This research contributes the criterion for such a methodology, the methodology, and the findings and results of applying it to two agencies, the Department of Commerce (DOC) and the Department of Energy (DOE).

RESEARCH OVERVIEW

Emerging and converging technologies can be the foundation for important breakthroughs (Alford et al. 2012; Bainbridge and Roco 2005; Roco 2007, 2011; Roco et al. 2013). For example, additive manufacturing via 3D printers can provide on-demand objects that solve immediate problems for government researchers or employees. Advances in cognitive science could improve comprehension and speed learning, making it easier to conduct research or handle office work. Nano-strengthened materials could become core, reusable building materials in smart homes. Each of these solutions requires emerging technologies, technologies that are so new that they are still being researched, developed, and applied to problems (Christensen 1997; Cozzens et al. 2010; Daim et al. 2006). Emerging technologies can be from any category of technology and are distinguished by their inevitability. Emerging technologies also can converge with other technologies or on platforms such as a computer, phone, or car to form converging technologies (Bainbridge and Roco 2005; Daim et al. 2009; Kelly 2010; Nordmann 2004; Seelman 2008; Roco 2011; Roco et al. 2013). For example, the technologies for email converge on a variety of platforms so that we can read email on our watches or on our windshields.

As part of a doctoral dissertation research project, a methodology was developed to characterize current and potential use of emerging and converging technologies to fulfill federal agency strategies. Designed to be implemented in four phases—develop, apply, evaluate, disseminate—methodology steps include definition, collection, organization, analysis, synthesis, evaluation, and dissemination (see Figure 1). Within the analyze step, foresight is incorporated by employing a mix of qualitative and quantitative analysis approaches to answer



Phase 1 / Developing the Methodology

Define

Define the problem to identify current and potential United States Federal agency use of emerging and converging technologies to fulfill agency strategies. Define the design criteria

Phase 2 / Applying the Methodology

Collect

Inputs from People	Inputs as Data
Government employees Research scientists Online crowd	Open source Proprietary

Inputs from People	Inputs as Data
Government employee interviews Expert assessments Crowd-sourced website tool	Government reports Online articles Online datasets Academic literature

Organize

Enter and classify

Analyze

Approach 1: Content analysis	Approach 2: Technology assessment analysis	Approach 3: Individual interviews	Approach 4: Plausibility matrix analysis	Approach 5: Crowd-sourced intelligence

Synthesize

Identify Current Use of Emerging and Converging Technologies	Identify Potential Use of Emerging and Converging Technologies
▪ Table of strategies and technologies per content analysis ▪ Table of strategies and technologies per technology assessment analysis ▪ Table of strategies and technologies per individual interviews	▪ Table of strategies and technologies per individual interviews ▪ Table of strategies and technologies per plausibility matrix analysis ▪ Table of strategies and technologies per crowd-sourced intelligence

Phase 3 / Evaluating the Methodology

Evaluate

Reconsider defined problem and the resulting methodology
Identify gaps in developing, applying, evaluating, and disseminating
Analyze gaps per Approach 6: Visual analytics
Assess the methodology versus the design criteria

Phase 4 / Disseminating the Methodology

Disseminate

Outreach with methodology and results to researchers per best practices
Outreach with methodology and results to policymakers per best practices
Outreach with methodology and results to the general public per best practices

FIGURE 1. Developed Methodology with Phases (inspired by "Conceptual Process Flow for the Persistent Forecasting System" (National Research Council, Committee on Forecasting Future Disruptive Technologies 2009, 59))

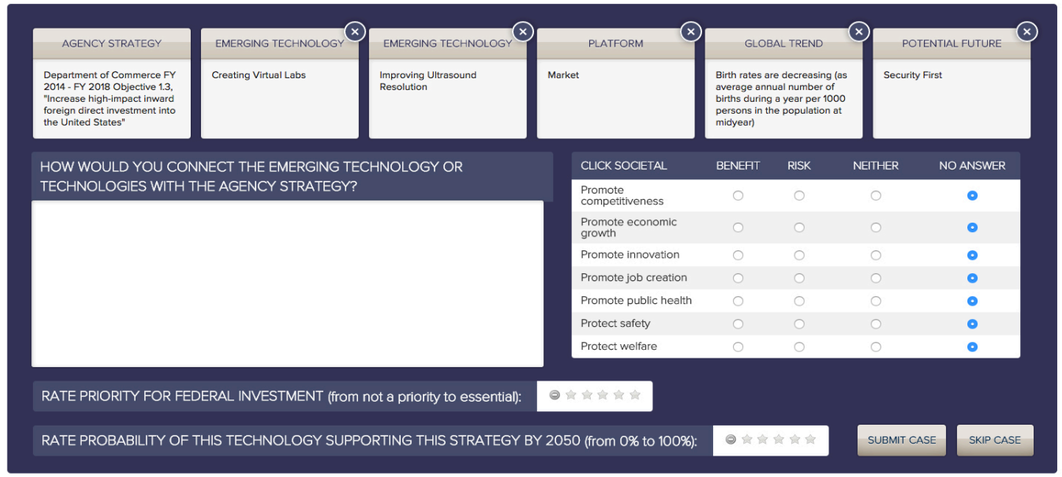
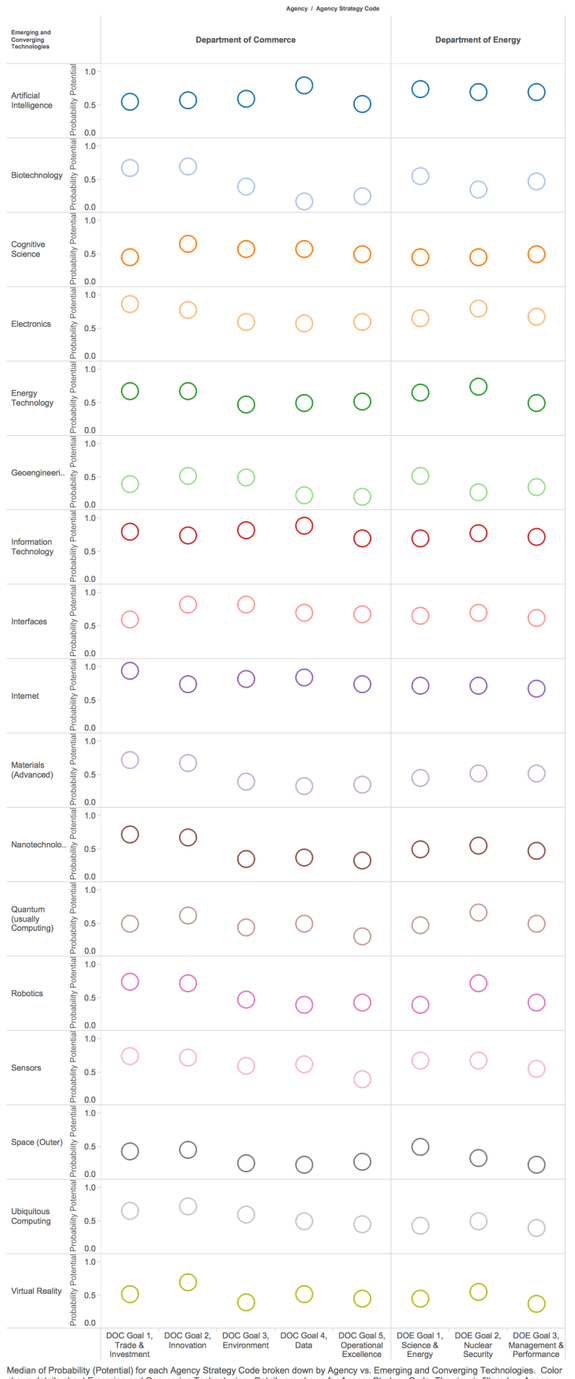


FIGURE 2. Sample from the "Connect Technologies" Game at www.foresightchallenge.org



Median of Probability (Potential) for each Agency Strategy Code broken down by Agency vs. Emerging and Converging Technologies. Color shows details about Emerging and Converging Technologies. Details are shown for Agency Strategy Code. The view is filtered on Agency Strategy Code, which has multiple members selected.

FIGURE 3. Approach 4 (outreach)

defined questions about the future so that policymakers can strategize and make decisions. Current agency use of emerging and converging technologies is characterized with content analysis of strategic documents; technology assessment analysis by experts; and individual interviews with government employees. Potential agency use of emerging and converging technologies is characterized with individual interviews with government employees; plausibility matrix analysis by experts; and crowd-sourced intelligence. The methodology was applied in Phase 2 to two cases, the Department of Commerce and the Department of Energy, then evaluated in Phase 3 versus the design criteria and visual analytics, and disseminated in Phase 4 to researchers, policymakers, and the general public.

One of the most interesting analysis approaches, crowd-sourced intelligence, involved creating a website through which the general public could connect emerging and converging technologies to agency strategies while factoring in platforms; trends and forecasts; and potential futures (see Figure 2). Users also rated answers based on priority for investment and technical feasibility. The games, data, and complete findings and results from this research project are available at www.foresightchallenge.org.

FINDINGS AND RESULTS OVERVIEW

The findings and results from this research are consistent: Developing and applying this methodology revealed a gap between the emerging and converging technologies DOC and DOE are using and could be using. Across the various analysis approaches, the following emerging and converging technologies were consistently identified for potential additional uses to fulfill all of the agency strategies: artificial intelligence, biotechnology, electronics, energy technology, information technology, interfaces, Internet, and sensors. Figure 3 displays a sample breakdown of the potential additional uses to fulfill agency strategies based on a particular analysis approach, the plausibility matrix analysis. On a probability scale from zero to one, experts rated the technical feasibility of the particular technology fulfilling the particular strategy by 2050. Reading the figure by row highlights the emerging and converging technologies that could be consistently helpful across strategies; reading the figure by column highlights the emerging and converging technologies that could be consistently helpful for a particular goal.