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## Practical Applications of Foresight Approaches in U.S. Analytical Studies of S&T Futures

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### Purpose

Foresight activities at the U.S. National Research Council have a long history (nearly 150 years) and have occurred under various names. They are best known in the form of evidence-based analytical studies of particular scientific, engineering, medical or societal issues that provide not only state-of-the-art snapshots of the underlying science but also analyse future needs to maximise gains for science, engineering and medicine as well meeting society's goals. The impact of the studies is on policymakers, programme managers, the various research sectors (academic, industrial etc.) and the informed public.

### Defining Needs for Foresight

In the U.S., the importance of science and technology (S&T) as components of decision-making by the legislative and executive branches of government is well-established. Even when policy issues are not overtly focused on S&T, decision-makers often seek an empirical basis for the outcomes of deliberations. Thus, foresight can be important for writing new laws, establishing and reviewing regulations, improving government programmes, influencing leaders in education and industry and establishing international collaboration.

The National Research Council (NRC) was established in 1917 as the operating arm of the National Academy of Sciences (founded 1863) to carry out a wide range of activities that bring together the top scientific experts to meet the government's needs outlined above. This paper, therefore, will identify both the typical needs addressed through this process as well as the capacities of the NRC in meeting them.

#### Defining Needs by Field

The natural inclination of active scientists is to identify problem areas for foresight studies by scientific field. This approach responds to the structure of some government research-funding agencies, particularly where the agency is primarily organised by field (e.g., National Science Foundation) or where an agency domi-

nates the government support of a particular field and is thus concerned with the long-term issue of particular scientific fields. It is also relatively simple to identify the top experts in such fields in the research community since they organise by such fields. Typical examples of topics covered in NRC reports developed along such lines are:

- *Astronomy and Astrophysics in the New Millennium*
- *Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond*
- *The Sun to the Earth – and Beyond: A Decadal Research Strategy in Solar and Space Physics*
- *Connecting Quarks with the Cosmos: Eleven Science Questions for the New Century*
- *New Frontiers in the Solar System: An Integrated Exploration Strategy*

#### Defining Needs by Problem Area

More frequently, the need for foresight analysis is expressed as a problem that requires integrating several fields. The complexity of societal challenges is increasingly well-understood and, as a result, the knowledge needed for sound public policy decisions cannot be found in one scientific realm only. Even government agencies, once seen as singularly focused on a particular discipline, are now reaching extensively across other



fields – note, for example, the National Institutes of Health – where they engage in widespread hiring of scientists from engineering, computer science, physics, chemistry and the social sciences.

There is also a strong democratic element to this definition of needs. The public and their elected representatives are increasingly inclined to turn to S&T for answers to problems in their lives. This leads to very broad-scale, integrated approaches to the NRC for analysis. Some recent examples include:

- *Implementing the New Biology: Decadal Challenges Linking Food, Energy, and the Environment*
- *Sustainability Linkages in the Federal Government*
- *Abrupt Climate Change: Inevitable Surprises*
- *The Future of the Nuclear Security Environment in 2015*
- *America's Energy Future: Technology and Transformation*

#### Defining Needs by Government Agency

Given the original mandate of the NRC to respond to analytical needs of government agencies, which is no longer exclusively true, there is a continuing flow of requests from such agencies to assist in setting priorities, identifying future helpful and threatening trends, and defining the parameters of where government investments would achieve the greatest returns.

This need can apply to an entire research portfolio in an agency, or it can focus on just one essential element in the work of an agency. It can address high-level strategic questions or simply the state of a specific research programme. While U.S. agencies now

have a wide range of advisory bodies that they create and appoint for their own uses, it remains true that they sometimes need the independent view of a non-governmental NRC with both credibility and independence. For that reason, it is a special kind of foresight need where the assistance of the NRC is sought, whether to serve as a third party to deal with disagreements among agencies or to assist the executive branch in its relationships with the U.S. Congress or with the public. It should be noted as well that many of the requests for studies that come from Congress are focused on a given agency, as legislators attempt to have their oversight activities better informed by advice from the NRC.

Some recent examples include:

- *Incorporating Sustainability into the U.S. EPA*
- *Setting Priorities for Large Research Facility Projects Supported by the National Science Foundation*
- *Toward a Sustainable and Secure Water Future: A Leadership Role for the U.S. Geological Survey*
- *Fostering Visions for the Future: A Review of the NASA Institute for Advanced Concepts*

These three areas of needs are not mutually exclusive, but the core approach of a foresight study does drive the type of expertise needed when appointing the committee to oversee the work. Each need also implies the kind of audience that will comprise the principal readers for the final report, and the authors need to keep them in mind as they deliberate. In the end, the authoring committees are only providing advice, not determinative decisions.

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## Capacity of the National Research Council

The NRC has built up a range of approaches to meeting the needs described above over many years, with the essential categories being consensus studies, convening activities and operational programmes.

Like no other organisation, the NRC can enlist the nation's foremost scientists, engineers, health professionals and other experts to address S&T issues. Each year, more than 6,000 of these experts serve on hundreds of study committees that are convened to answer a specific set of questions. All serve without pay. Through a careful process of committee selection, gathering of information from many sources in public meetings, deliberation over the findings and recommendations, the NRC produces 200-300 reports each year.

Foresight studies require a special approach to deliberation, since the expert members are sometimes

asked to go beyond the evidence of scientific proof. They are required to express their judgements with great care and with due conditions to avoid giving the impression they are "predicting" the future. Thus, the methodologies often utilise roadmaps, scenarios, decision trees, gaming and surveys.

Some of the foresight activities revolve around the organisation of workshops, which are more flexible in their participation and not always required to produce a consensus view among the organising committee. In cases where the problems are not as well defined, the best purpose of NRC involvement is in convening a sufficiently broad set of experts from multiple fields to simply establish a dialogue among experts. Here the report of the committee is meant to serve as informing the expert community as much as anyone about the shape, scope and size of the challenge so that the next iteration of study or convening activity can advance to the next plateau of understanding.

Carrying out effective foresight studies requires a judicious combination of continuity and change. The continuity comes from the carryover of experts from one study to the next, combined with a professional staff at the NRC (total 1,400) that has an ongoing dialogue with all elements of the S&T and policy communities. The change comes from younger researchers, continuously fed into the collegial process of research, consultation, participation and dissemination of foresight analysis at

the NRC. In recent years, the NRC has particularly focused on the need to internationalise its foresight activities and increasingly sees them as “global endeavours”, in part to match the functional collaboration between researchers on all continents. The tendency of multinational corporations with research divisions has reinforced this perspective, and it now appears to be irreversible.

### **Audiences: From Governmental Agencies to Individual Users**

The broadening of interest in all things scientific and technical in the US has spurred a need to expand the ability of the NRC to communicate its findings and recommendations to multiple audiences. The traditional targets have been agencies of government, and over time, the role of Congress in actively shaping policies and programmes has led it to be a prime consumer as well for foresight exercises that identify priorities and strategic direction. More recently, the research community itself has looked to NRC studies for not only sound judgement and the use of peer-reviewed evidence, but also for careful advocacy for the research enterprise in a political jousting ground. Broader audiences also have learned to use foresight studies for their own planning; for example, as students plan their careers, they may look to decadal studies to see if they find scientific prospects matching their interests.

Demonstrable outcomes from foresight studies are even more important for the NRC process, if only because the expertise that comes from participants of the research community is given on a volunteer basis.

They need to know that their investment of time, knowledge and judgement is for a good and effective purpose. As a result, the NRC maintains nearly 100 standing bodies (usually committees with 15-30 members) that track both the state of their assigned fields and the impact of their studies. They observe a number of possible outcomes, but four stand out:

- Changes in research investments, particularly in principal-investigator led programmes at federal science agencies
- Patterns of government investment in research infrastructure
- The scale and purpose of training programme investments, the life blood for graduate student and postdoctoral scholar programmes.
- Maintenance of appropriate databases on the research enterprise and its various components

One overall measure of the impact of NRC foresight reports is the recent institutional decision to make all publications available at no cost as online PDFs. The demand had grown, both domestically and abroad, to the point that the obligation to make its work maximally available ensured taking that policy step.

### **NRC: Fact Producing, Priority Setting, Innovation-oriented and Disruption-sensitive Foresight Experience**

A number of lessons have emerged in recent decades via the growth in foresight-type activities by the NRC. While there are many lessons in terms of implementation, this section will focus on the strategic level.

1. While the trend in requests for foresight activities is towards broad problem-solving with multiple disciplines involved, foresight exercises must be sure at the end of the day to emphasise the science of the issue. It is all too easy to want to become “relevant” when the statement of task is defined as a public policy challenge. The strength of the S&T community is the research base that produces facts rather than political opinions. Straying into the realm of opinion reduces the research community to just one more voice among many.

2. The NRC is often asked to set priorities, and some expert committees shy away from such a challenge. So long as the committee has an objective basis for making the recommendation, it should respond positively rather than being scared away from a challenge that may imply a set of “winners” and “losers”. Over time, it will result in priority-setting being done in a more rational way than if left to the non-S&T community to make those choices.
3. Foresight exercise participants are tempted to stick to the fundamental science rather than including the applications of science. If the findings of the committee are appropriately hedged for the uncertainties of applied science, there is a significant contribution to be made by the S&T community to a more complete understanding of the innovation process. The general public and policymakers often come from fields where they are not familiar with the difficulties that arise in moving from basic research through many steps to products on the shelf to benefit the public. It

is particularly important to lay out the time required for that process – for example, stem cell research undertaken today is going to have a long gestation period for generalised benefits to accrue to the population tomorrow.

4. Foresight analysis is always subject to low-probability, high-impact developments that derail our expectations based on past experience. These disruptive events can come from within science, in an unexpected discovery, or they can come from without in a massive challenge to societal and economic health. Examples come both from science fiction and

from nature – whether the collapse of the Gulf Stream, geo-engineering, new zoonotic diseases or wireless power transmission. Some people attempt to build such developments into foresight – say, through “weak signal analysis” – and it probably has a specific but limited place, even if we have demonstrated our vulnerability to such events.

5. The pursuit of foresight analysis needs consistent follow-up, perhaps on a continuing basis. The NRC finds that most of its foresight studies, often decadal projections, can use an update within about five years.

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## Sources

Project home page: <http://www.nationalacademies.org/nrc/index.html>

For reports cited above: <http://www.nap.edu/>

For further information about the study process: <http://www.nationalacademies.org/nrc/policies.html>

The views expressed above are those of the author and do not necessarily represent the views of the National Research Council or any of its constituent units.

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**About the EFP:** Policy professionals dealing with RTD, innovation and economic development increasingly recognize a need to base decisions on broadly based participative processes of deliberation and consultation with stakeholders. Among the most important tools they apply are foresight and forward looking studies. The EFP supports policy professionals by monitoring and analyzing foresight activities and forward looking studies in the European Union, its neighbours and the world. The EFP helps those involved in policy development to stay up to date on current practice in foresight and forward looking studies. It helps them to tap into a network of know-how and experience on issues related to the day-to-day design, management and execution of foresight and foresight related processes.