

# Managing Innovation Prizes in Government



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## FOREWORD

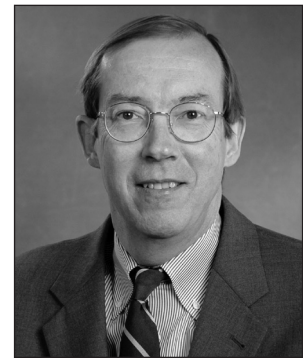
On behalf of the IBM Center for The Business of Government, we are pleased to present this report, *Managing Innovation Prizes in Government*, by Luciano Kay, School of Public Policy, Georgia Institute of Technology.

“Award” prizes—as opposed to “recognition” prizes such as the Nobel or Pulitzer prizes—are a growing element of how government is trying to spur innovation in solving tough problems both inside and outside the government. Why? It’s because well designed/implemented prizes have been found to be effective. Under special circumstances, they may be even more effective than traditional policy instruments in research and development such as grants and contracts.

Prizes can be used to achieve multiple goals. In this report, author Luciano Kay surveys the literature and presents three case studies of recent prizes awarded for technology development-related achievements: the Ansari X Prize for the first private reusable manned spacecraft, the Northrop Grumman Lunar Lander Challenge for flights of reusable rocket-powered vehicles, and the DARPA Challenges for autonomous road vehicles.

Prizes and competitions are also a visible element of the Obama administration’s efforts to promote innovation in government. For example, the Office of Management and Budget (OMB) has sponsored a competition among federal employees to find cost savings and the White House has created the Challenge.gov website where federal agencies can pose problems in the hope of getting solutions from both the public and government employees. OMB has issued guidance to encourage agencies to offer challenges and prizes, as well.

The use of prizes by government gained a legislative boost in December 2010 when the United States Congress included a prize component in legislation designed to increase American innovation and competition. This new legislation expands the authorization to use prizes to every agency head, and creates a framework that eases existing administrative constraints for conducting a prize competition for those outside government.

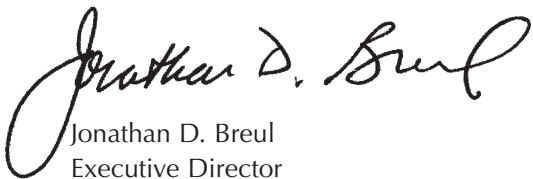


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Drawing upon those recent prize experiences and considering the need for better methods to manage prizes in government, this report offers practical insights and recommendations for the design, implementation, and evaluation of innovation prizes that can benefit agency managers who are interested in understanding whether, and how, they should do so. We hope you find it to be an inspiring and practical guide to innovation prizes.



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## EXECUTIVE SUMMARY

Innovation prizes are contests in which cash rewards are given to incentivize technological innovation. In recent years, scholars and prize advocates have increasingly called attention to the potential of prizes to induce technological innovation and accomplish broader economic and societal goals. To date, there has been little empirically-based scientific knowledge on how to design, manage, and evaluate these competitions.

This report offers practical insights and recommendations for the design, implementation, and evaluation of innovation prizes sponsored or organized by government agencies for technology development or achievement of other mission-related goals. The report includes insights from the broader prize literature and discusses how different aspects of prize design may lead to more effective and efficient prize-based public programs.

This report draws on three cases of recent prizes widely regarded as successful technology programs:

- The Ansari X Prize (privately funded and organized by the X Prize Foundation)
- The Northrop Grumman Lunar Lander Challenge (NGLLC)
- The Grand and Urban Challenges of the Defense Advanced Research Projects Agency (DARPA)

These cases are a valuable source of prize competition experience in technologies with unique relevance for the strategic U.S. aerospace and defense sectors. Moreover, these cases represent different prize implementations and present diverse lessons for program managers working in other sectors as well. The Ansari X Prize was a privately-sponsored prize that sought to accomplish goals that exceeded

technological development. The NGLLC and the DARPA Challenges were short-term, government-sponsored prizes that sought to accelerate commercial development and the creation of research communities for specific technologies, respectively.

These three prize experiences emphasize the importance of working carefully on all aspects of the design, implementation, and evaluation of the program, in order to have a successful prize. Most importantly, a proper design requires:

- Defining an exciting prize challenge
- Setting a prize reward that considers commercial opportunities and other non-monetary benefits of participation for prize entrants
- Crafting simple and transparent prize rules
- Defining a scheme to finance the program that considers alternative funding sources

For the implementation of the program, sponsors should:

- Collaborate and seek co-sponsors or allies
- Use strategic opportunities to announce the prize and make it visible
- Respond to the feedback from entrants
- Select winners objectively

The evaluation of the program should consider different metrics of effectiveness and efficiency, and not lose sight of the fact that prizes may have different impacts during the competition and in the longer-term.

The findings of this research suggest practicable recommendations to increase the impact of prize



programs and inform the decision to use prizes in different circumstances. The insights contributed by this report are largely based on findings and lessons learned from a research project by the author that investigated how prizes induce innovation in the aerospace technology sector. This report also includes the lessons learned from the defense-related DARPA Challenges. The author's research on prizes draws upon multiple data-gathering methods, such as document analysis, questionnaires, and interviews with prize participants and prize and industry experts.

# Introduction

Prizes have long been used to stimulate individuals, groups, and communities to accomplish a wide variety of goals. Lately, policymakers, program managers, philanthropists, academic researchers, and the media have become increasingly interested in prizes due to their potential to induce path-breaking technological innovations or achieve related goals such as economic recovery, the engagement of diverse social groups with science and technology, technology diffusion, and the creation of innovation communities. This report focuses on prizes that are aimed not only at inducing technological innovation, but also may help to accomplish other goals related to technological development.

## A Brief History of Prizes

Prizes are incentives that have long been used by public or private sponsors to elicit effort of individuals and organizations. For instance, in the 18th century, prizes were used to encourage basic research by compensating research results with monetary rewards or medals (Brunt et al., 2008; Harford, 2008). Prizes also helped in the initial development of the aviation industry in the early 20th century (Davis & Davis, 2004). Notable prizes in history are for example the government-sponsored prize offered by the British Parliament in 1714 to the first to invent an instrument for accurately measuring longitude at sea, and the privately funded Orteig Prize for the first aviator to fly nonstop from New York to Paris (won in 1927 by Charles Lindbergh).

The technology problems that have been more commonly tackled with prizes vary according to recently compiled datasets of prizes (Masters & Delbecq, 2008; McKinsey & Company, 2009; Stine, 2009). Aviation and aerospace, climate and environment, and medicine have been historically among the top

areas. Other areas in which prizes have been used to a lesser extent include transportation (including automotive), energy, defense, computing and software, and chemistry. In spite of such diversity, a significant use of prizes in the aviation sector since the early 20th century, and in aerospace since the 1990s, suggests that prizes may be more effective in these fields and in related technology applications.

A number of studies have addressed the use of prizes in the U.S. government since the late 1990s, such as those by the National Academy of Engineering (NAE, 1999) and the National Research Council (NRC, 2007). More recently, several federally funded innovation prizes have been authorized since 2003. These prizes have been aimed at inducing research, development, testing, demonstration, and deployment of technologies (Stine, 2009). For example, NASA has used the Centennial Challenges prizes to attract new entrepreneurs to aerospace technology development. The U.S. Department of Defense has used prizes to find innovative solutions in defense-related technologies, with, for example, the Wearable Power Prize to develop long-endurance, lightweight power packs for war fighters, and the DARPA Grand Challenges to develop autonomous ground robotic vehicles. The Department of Energy and the Department of Health and Human Services have developed prizes as well. Most of these prizes have offered cash rewards between \$250,000 and \$10 million to solve challenges related to the organizations' missions.

More recent initiatives at the federal level include Challenge.gov, an online platform administered by the U.S. General Services Administration (GSA) to gather the public's ideas and talent through challenges and competitions. More than 20 departments and agencies have already launched competitions

## Increased Prize Activity in the Federal Government

There was much increased interest by the federal government throughout 2010 in the use of prizes. It is anticipated that there will be continued increased activity and interest throughout 2011. During 2010, new legislation was enacted to support the use of prizes by federal agencies. In addition, an increased number of prizes were announced on the Challenge.gov website.

### The America COMPETES Reauthorization Act of 2010

The America COMPETES Act provided all federal agencies with broad authority to conduct prize competitions and includes provisions for different aspects of prize design, implementation, and oversight. In particular, this Act authorizes the use of prizes for one or more of the following:

- Find solutions to well-defined problems
- Identify and promote broad ideas and practices and attract attention to them
- Promote participation to change the behavior of contestants or develop their skills
- Stimulate innovations with the potential to advance agencies' missions

The legislation also allows agencies to accept funds for cash prizes from other federal agencies and the private sector, allows agencies to enter into agreements with private, nonprofit entities to administer a prize competition, and requires reporting prize activity for each fiscal year.

In addition, the Act also requires the Director of the National Science Foundation to carry out a pilot program to award innovation inducement cash prizes in any area of research supported by NSF. The legislation authorizes the Director of NSF to announce up to five prize competitions through FY2013 with prize awards based on the prize topic, but prohibits the amount of any award from being less than \$1 million or greater than \$3 million.

### Increased Number of Prizes Announced on Challenge.gov

As of January 2011, there were over 55 announced competitions on the Challenge.gov website. The prize awards ranged from relatively small amounts of money (\$200) to large amounts of money (\$15 million).

Among the recent competitions with the largest prize awards posted on Challenge.gov are:

- **The Bright Tomorrow Lighting Prize (\$15,000,000):** Sponsored by the U.S. Department of Energy, the L Prize competition is aimed to substantially accelerate America's shift from inefficient, dated lighting products to innovative, high-performance products. The L Prize is the first government-sponsored technology competition designed to spur lighting manufacturers to develop high-quality, high-efficiency solid-state lighting products to replace the common light bulb.
- **The Progressive Automotive X PRIZE (\$10,000,000):** The U.S. Department of Energy, Progressive Insurance, and the X PRIZE Foundation partnered to sponsor this prize, which was awarded in 2010. The goal of the prize was to inspire a new generation of viable, super-efficient vehicles that help break our addiction to oil and stem the effects of climate change. A project of the X PRIZE Foundation, the Progressive Automotive X PRIZE was an independent, technology neutral challenge for teams from around the world to compete in a multi-stage competition to produce clean, production-capable vehicles that exceed 100 miles-per-gallon energy equivalent (MPGe).
- **The Strong Tether Challenge (\$2,000,000):** NASA sponsors this challenge in materials engineering as part of its Centennial Challenges. The tether developed by each team is subjected to a pull test and, in order to win the \$2 million prize, the tether must exceed the strength of the best available commercial tether by 50 percent with no increase in mass. A tether that can win this challenge would be a major step forward in materials technology. Such improved materials would have a wide range of applications in space and on Earth.
- **The Nano-Satellite Launch Challenge (\$2,000,000):** Another NASA Centennial Challenges prize competition is to deliver two small satellites to Earth orbit in one week. Objectives of the competition include:
  - Safe, low-cost, small payload delivery system for frequent access to Earth orbit
  - Innovations in propulsion and other technologies as well as operations and management for broader applications in future launch systems
  - A commercial capability for dedicated launches of small satellites at a cost comparable to secondary payload launches—a potential new market with government, commercial, and academic customers

through this platform. The prizes analyzed in this report, however, are typically on a larger scale and seek to harness different types of resources to advance the sponsor's goals.

## The Structure of Innovation Prizes

Innovation prizes are typically organized as competitions in which participants are asked to solve pre-specified technological *challenges* or meet *targets* before a deadline.

The prize challenge represents a gap in technology that has to be reduced or closed by, for example, increasing technology efficiency or delivering new technical solutions. The challenge is defined by a prize sponsor interested in accomplishing certain goals by offering what is generally a cash reward to the first prize entrant to achieve that challenge. If no entrant does that by the established deadline, the prize expires and the sponsor does not have to pay the reward.

A prize sponsor may be an individual, a private organization, a government agency, or some combination of them. The prize participants or entrants are generally organized as teams of diverse composition and may include companies, universities, entrepreneurs, or simply individuals attracted by the prize.

Prizes can be structured in different ways:

- In **“first-to-achieve” prizes**, the challenge is usually defined as a concrete technological goal that entrants have to achieve before the deadline or expiration date to claim the cash purse. The first entrant to achieve the challenge is considered the winner.
- In **“best-in-class” prizes**, the challenge is defined as a set of minimum standards of performance that entrants have to attain to be eligible to claim the cash purse. In this case, the winner is the entrant that performs the best according to those standards.

In “best-in-class” prizes, there is typically a main public event organized by the sponsor in which all participants come together to compete to claim the cash purse. In this case, the challenges may also be defined as a set of intermediate milestones or qualifying rounds to guide the effort of the participants and permit only the

most qualified entries to be selected for a final challenge. If no participant achieves the minimum standards required by the sponsor in that final event, the prize is considered expired.

On the other hand, prize competitions can be structured to award all the prize money to the winner (“winner-takes-all” competitions) or may offer additional rewards for the second or third place winners as well.

## Types of Impacts from Prizes

Prizes may help government agencies to advance their missions and accomplish other related goals through competitive research and development programs. In particular, prizes may prompt four main types of impacts:

- Developing technology
- Leveraging R&D investment
- Promoting entrepreneurship
- Raising awareness by engaging different communities and attracting public attention to areas and issues of interest for the agencies

This report focuses on the four types of impacts as alternative program goals, but in time innovation prizes may induce other diverse outcomes as well.

### Developing Technology

The impact of prizes on technology development may manifest in different ways. Properly designed prizes may accelerate the speed of technology development, incentivize creativity that leads to new inventions, promote the introduction, application and diffusion of existing technologies, stimulate performance improvements, and bring on new forms of R&D organization. Prizes also create a competitive environment that enables the direct evaluation and comparison of rival technological approaches and helps to identify new technical solutions to critical problems. Although sponsors typically focus on producing one of these effects, prizes tend to have multiple impacts.

### Leveraging R&D Investment

Prizes also have the capacity to leverage R&D investment and attract funding from sectors not

### Generic Examples of Applications of Prizes to Technology Development-Related Goals

- Explore new, experimental technologies that imply high-risk R&D
- Explore new, innovative approaches to break critical technological barriers
- Incentivize the development of cheaper or better-performing solutions based on existing technologies
- Accelerate the application, diffusion, and commercial development of technologies
- Raise public or industry awareness and change beliefs about science and technology topics linked to the agency's mission

commonly involved in technology development. Moreover, since cash rewards are generally paid only when there are concrete results (that is, when there is a winning entry), properly designed prize-based programs shift the risk of technology development to the prize entrants and may have higher payoffs than traditional technology programs. Still, since the characteristics of the technical solutions that come out are generally unpredictable, prizes introduce higher uncertainty than traditional programs, even when they are meticulously planned and implemented. With prizes it is also difficult to foresee who the ultimate participants will be, and what overall incentive effect the program will have.

### Promoting Entrepreneurship

Well-designed prizes can both promote entrepreneurship and engage diverse groups by reducing barriers to participation often in place in traditional programs. In addition to traditional companies and professionals, new entrepreneurs, independent inventors, and students, among others, may be driven to engage in technology development via the creation of innovation awards. These unconventional entrants may bring new and fresh approaches, perceptions, knowledge, and ideas to the competition. Moreover, they may be less risk-averse than traditional companies and research organizations (Nalebuff & Stiglitz, 1983). This suggests that prizes can help to identify new entrepreneurs, incentivize research in areas not traditionally addressed in

industry or academia, stimulate the growth of new technical communities, and even explore riskier R&D approaches.

### Raising Awareness

Exciting prize challenges and competitions may also inspire and capture the attention of policymakers, industry executives, and the public, influencing perceptions and educating about different science and technology topics or societal issues associated with the sponsor's mission (NAE, 1999).

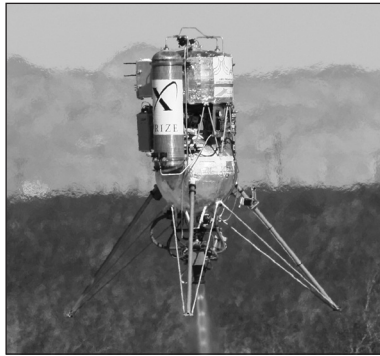
Prizes should be considered as an alternative, experimental policy instrument to complement other traditional technology programs such as research grants or procurement contracts. New, more documented prize experiences and growing research on prizes will inform the design and implementation of more effective and efficient programs in the future. Generally speaking, prizes may be appropriate when an agency's program goals can be defined in concrete terms, but the means to achieving the goal are too speculative to be addressed by a traditional research or procurement program (Kalil, 2006).



# Case Studies: Recent Prizes in the Aerospace and Defense Sectors



Ansari X Prize: The winning space plane SpaceShipOne in flight.



Northrop Grumman Lunar Lander Challenge: Masten Space Systems XA0.1E rocket.



The DARPA Urban Challenge: First place finisher, Tartan Racing.

The experiences, lessons, and recommendations presented in this report are based on three case studies of recent aerospace and defense prizes widely regarded as successful programs. They are the Ansari X Prize,<sup>1</sup> the Northrop Grumman Lunar Lander Challenge,<sup>2</sup> and the DARPA Grand and Urban Challenges.<sup>3</sup> Table 1 presents a summary of information about these prizes and Figure 1 shows a timeline for them. The research findings of these case studies and associated insights are the result of a research project the author undertook to examine the potential of innovation inducement prizes as policy tools.<sup>4</sup> This project uses multiple data sources including document analysis, questionnaires, and interviews with the program managers of these prizes.

The Ansari X Prize was announced by the X Prize Foundation in 1996. It offered a \$10 million cash purse for the first non-governmental organization to launch a reusable manned spacecraft into space twice within two weeks, to a minimum altitude of 100 km. This prize was privately funded and inspired by the early 20th century Orteig Prize for the first solo nonstop transatlantic flight between

New York and Paris. Twenty-six teams from seven different countries participated in the X Prize Competition. The competition was won in 2004 by Scaled Composites, a U.S. aircraft design company. This was the first prize program administered by the X Prize Foundation, an educational, non-profit corporation established in 1994 to inspire private, entrepreneurial advancements in space travel.

The Northrop Grumman Lunar Lander Challenge (NGLLC) was a multi-year competition held between 2006 and 2009 as part of the NASA Centennial Challenges program, which comprises about a dozen different prizes. Twelve independent, small U.S. teams participated in four years of competition. The NGLLC offered a total of \$2 million in cash prizes for the first and second best-performing teams. To win, teams had to build and fly a vertical take-off and landing rocket-powered aircraft within minimum, pre-specified standards of efficiency, and under conditions that simulate the same flight on the moon. This program had two competition levels with different degrees of difficulty (I and II, II being the most difficult); the prize money rolled over to

the next year when no entries qualified. In 2006 and 2007, the prize-winning attempts of all the teams took place at a sponsor-organized public event. The same format was used in 2008 but the event was not open to the public. In 2009, the teams were

allowed to designate their preferred site and date to attempt their flights. Masten Space Systems and Armadillo Aerospace, two aerospace startups, won different levels of this prize in 2008 and 2009 and shared the total prize money.

**Table 1: Summary of information for prizes analyzed in this report**

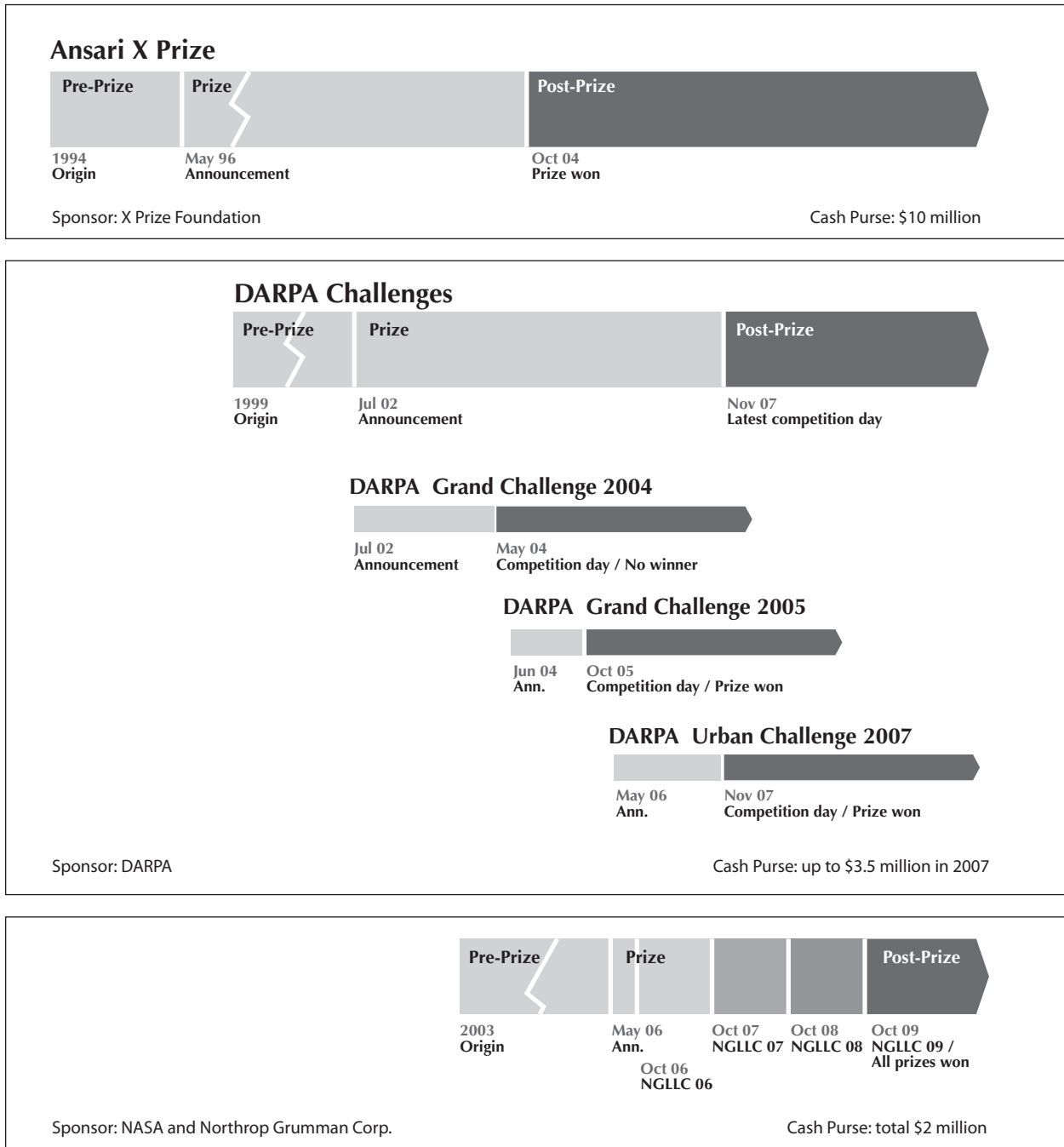
	<b>Ansari X Prize (1996-2004)</b>	<b>Northrop Grumman Lunar Lander Challenge (2006-2009)</b>	<b>DARPA Challenges (2004, 2005, 2007)</b>
<b>Prize challenge</b>	First non-governmental organization to launch a reusable manned spacecraft into space twice within two weeks	Build and fly a reusable, rocket-powered vehicle simulating a flight on the moon within pre-specified timeframe and performance, and in a designated location	Build an autonomous vehicle and complete a pre-specified course demonstrating ability to operate safely and effectively with other vehicles
<b>Sponsor / administrator</b>	X Prize Foundation (sponsor and manager) with funding from the Ansari family	NASA and Northrop Grumman Corp. (sponsors) / X Prize Foundation (manager)	DARPA (DoD)
<b>Prize purse</b>	\$10 million	<b>Level I:</b> \$350,000 for first place, \$150,000 for second place <b>Level II:</b> \$1 million for first place, \$500,000 for second place	\$1 million (2004); \$2 million (2005); \$2 million for first place, \$1 million for second place, \$500,000 for third place (2007)
<b>Prize type</b>	First-to-achieve prize; medium- or long-term prize	Best-in-class prize; multi-year prize with purse rollover	Best-in-class prizes; short-term prizes, similar challenges
<b>Prize entrants</b>	26 teams from seven countries	12 U.S. teams	All U.S. teams; Finalists (Applicants): 15 (104) in 2004; 23 (195) in 2005; 11 (89) in 2007
<b>Prize winners</b>	Scaled Composites, from Mojave, California (\$10 million)	<b>NGLLC 2006 and 2007:</b> No winners <b>NGLLC 2008:</b> Armadillo Aerospace from Rockwall, Texas: Level I (first place) for \$350,000 Masten Space Systems from Mojave, California: Level I (second place) for \$150,000 <b>NGLLC 2009:</b> Masten Space Systems from Mojave, California: Level II (first place) for \$1 million (2009) Armadillo Aerospace from Rockwall, Texas: Level II (second place) for \$500,000 (2009)	<b>Grand Challenge 2004:</b> No winners. <b>Grand Challenge 2005:</b> Stanford Racing from Stanford, California (\$2 million) <b>Urban Challenge 2007:</b> Tartan Racing from Pittsburgh, Pennsylvania (first place) (\$2 million) Stanford Racing from Stanford, California (second place) (\$1 million) Victor Tango from Blacksburg, Virginia (third place) (\$500,000)
<b>Similar prize examples</b>	Automotive X Prize (2010); Google Lunar X Prize (ongoing)	Power Beaming Challenge (2005, 2006, 2007, 2009, 2010)	Wearable Power Prize (2008)

Source: Author's analysis and sources cited in text

The DARPA Challenges are three competitions organized by DARPA, comprising the Grand Challenge, held in 2004 and 2005, and the Urban Challenge, held in 2007. This prize program offered cash rewards of \$1 million in 2004, \$2 million in 2005, and up to \$3.5 million in 2007 for the autonomous ground robotic vehicles that perform the best in pre-specified complex off-road and urban environments (in 2007 the prize was divided into first, second, and third places). The vehicles had to be built by the teams, complete a course of several miles with a time objective, and demonstrate their ability to operate safely and effectively with other vehicles. None of the 15 finalists won in 2004. In 2005, the winner was Stanford Racing Team from Stanford University, chosen from among 23 finalists. In 2007, the Tartan Racing team from Carnegie Mellon University won first place among 11 finalists. Competitors were U.S. teams, some with foreign membership, and included representatives of major automakers, DoD contractors, and universities. Overall, this prize program represented only a small share of the R&D activity that DARPA has conducted in this area.



**Figure 1: Timeline of prize cases: the Ansari X Prize, the DARPA Challenges, and the Northrop Grumman Lunar Lander Challenge**



Source: Author's analysis and sources cited in text

# The Challenge of Designing a Prize Competition

The experience, lessons, and recommendations presented in this report are based on the study of the three aerospace and defense prizes discussed in the previous section, as well as insights from the broader prize literature. The cases offer a valuable source of recent prize experience and present diverse lessons for future prize-based program implementation. Although part of that experience is at the federal government level and/or exemplified ambitious program goals, most of the considerations and recommendations of this report may also be valid for state or local prize programs and the pursuit of program goals of different scope and scale. The following examination of recent experiences, lessons, and recommendations covers the design, implementation, and evaluation of prize programs.

## Designing the Prize

Design is the pre-prize stage of prize programs. It defines elements such as the prize challenge, the prize reward, the eligibility to compete, the rules of the competition, and the sources of funding for the program. The design should also consider the intellectual property rights of the prize technologies and regulatory frameworks. This section presents each of these elements as recommended steps to design a successful prize program. Prize design is generally undertaken over the six to 12 months prior to the prize announcement, but the original idea or concept for the competition may have been conceived much earlier. Proper design and careful attention to detail is a requisite of every successful prize program. Different prize designs may produce significantly different program results, as described in the discussion below.

## Defining the Prize Challenge

Prizes can address diverse topics and types of achievements depending on the ultimate goals of the program. For example, a prize challenge may require the participants to deliver a prototype that performs according to certain standards, create a new method to solve an old technical problem, or accomplish a feat that involves the development and/or application of technology. Both the challenge and the lead time for technology development focus the effort of prize entrants and affect the approaches and solutions they come up with. Challenge definitions that are sufficiently vague incentivize the use of diverse approaches to technology development and problem solving, but also make it difficult to predict what the characteristics of the program's ultimate technology achievements will be. More detailed rules and technical specifications focus the R&D effort at the cost of less diversity and creativity.

The program goals implicit in these three aerospace and defense prizes are very different and, therefore, the scope, scale, and expected results of the competitions vary. Technology development had different roles in each competition. None of these prizes required delivering a prototype, but the three competitions demanded building a vehicle to accomplish their purpose.

In particular, the Ansari X Prize ultimately sought to demonstrate the feasibility of private space flight; change existing public opinion about private industry's capabilities; and generate concrete business opportunities (Maryniak, 2010). Therefore, the challenge required flying a vehicle with human transportation capabilities that considered the potential commercialization of the technology,<sup>5</sup> a minimum altitude to be considered a space flight (100 km),

and privately funded teams. The teams were allowed to use any technology and approach to accomplish this feat.

The NGLLC sought to accelerate the commercial development of technologies aligned with NASA's moon exploration plans and the broader goal of advancing entrepreneurship (Davidian, 2010). Therefore, its challenge, maintained during the four years of competition, required privately funded teams to build and operate vertical take-off and landing vehicles with certain operational capabilities and standards. Participation required flying a new vehicle, but teams could draw upon existing knowledge and components and improve or reconfigure them to meet the prize requirements and win the prize.

The DARPA Challenges focused on stimulating the research community to develop the technologies that DoD needs to meet Congress's mandate for using unmanned vehicles (Whitaker, 2010).<sup>6</sup> Therefore, these challenges required building and operating autonomous robotic vehicles with certain operational capabilities. Teams were allowed to draw upon extensive resources (including government-funded resources) from industry and universities, among others, to develop their technologies.

Four common design features characterized the challenges of the three case study prizes.

- First, they were defined at the level of technology systems rather than individual technology components.
- Second, they were associated with early stages of technology development and demonstration, rather than commercialization. Still, the Ansari X Prize sought to incentivize solutions that might have commercial value and the DARPA Challenges addressed technologies with potential application in civilian transportation.
- Third, their potential and technical feasibility were brainstormed and evaluated in consultation with industry or technology experts, entrepreneurs, and would-be prize entrants. For example, NASA organized workshops to generate dozens of ideas for the Centennial Challenges program with participation of entrepreneurs and industry experts.

- Fourth, they were exciting challenges that captured the public imagination and attracted groups of people with diverse backgrounds to technology development.

### **Sponsor Considerations**

- Agencies should define a prize challenge that is exciting and ambitious yet still doable. It should be clearly enunciated and easy to communicate, and above all, be simply defined so that it is obvious when a participant has achieved it.
- The prize definition should be sufficiently vague as to allow the introduction of innovative approaches and creative solutions.
- Prize challenges linked to commercial opportunities or "after-prize markets" are more attractive and can significantly increase the impact of the program (further discussed in the next section).
- The prize deadline should allow reasonable lead-time for technology development and be aligned with other programs set by the agency. In multi-year programs, challenges should be redesigned over time to ensure exciting competitions.
- Agencies should evaluate the feasibility of prize ideas with entrepreneurs and industry experts. When there is no previous experience, agencies should first implement less ambitious and short-term prizes as experimental programs.

### **Setting the Prize Reward**

In prize programs, sponsors pay only for concrete results that satisfy the requirements of the prize challenge. Still, recent experiences show that the cash purse generally covers only part of the R&D costs to win the prize. For example, Scaled Composites spent about \$30 million to win the \$10 million Ansari X Prize (Linehan, 2008) and Masten Space Systems spent about \$2.5 million to win \$1.15 million in the NGLLC (Morring, 2009). This suggests that prize entrants are motivated not only by cash rewards, but also by other incentives implicit in these competitions. Prizes may offer the opportunity to increase knowledge, gain credibility or boost one's reputation, or pursue commercial opportunities linked to the prize technologies, among other benefits. Such diverse incentives may even be the prime motivator attracting unconventional entrants, rather than the monetary rewards (Kay, 2010).

The competitions examined in this report were actually designed to attract such unconventional entrants, rather than the traditional industry players. For example, the cash purse of the Ansari X Prize was defined to be “large enough...to be of interest [to] the community and not so large that the traditional aerospace industry players would be attracted to it” (Maryniak, 2010). Prize managers also explain that cash rewards were calculated to be attractive to entrants and cover at least part of the costs of technology development (Davidian, 2010; Whitaker, 2010). In the DARPA Challenges, program managers even considered offering a non-monetary reward (Whitaker, 2010).

These competitions were also more or less aligned with commercial opportunities. For example, the autonomous vehicle technologies of the DARPA Challenges have potential widespread use in industrial and civilian applications as well. In the case of the NGLLC technologies, there was no clear consensus about the commercial value of the prize technologies when the prize was announced, but the sponsorship of NASA and Northrop Grumman may have suggested the possibility of future contracts. The Ansari X Prize, for its part, helped to raise awareness about the emerging opportunities in the human space flight transportation market.

On the other hand, strong non-monetary incentives complemented the cash purses of these prizes. Most importantly, these three competitions offered volunteers and independent inventors the opportunity to enter a field typically reserved for government or corporate R&D. These prizes also engaged students who sought to gain a unique hands-on experience. The DARPA Challenges offered universities and companies an opportunity to demonstrate technological leadership in the robotics and transportation fields, strongly linked to academic and corporate R&D (Whitaker, 2010). In 2006 and 2007, the NGLLC competitions also offered teams a special opportunity to demonstrate their technological prowess in public events before government and corporate officials (XPF, 2007).

### **Sponsor Considerations**

- There is no single rule for determining the proper size of the cash purse. Some experts consider a cash purse of one-fourth to one-third of the expected costs of R&D to achieve the prize challenge appropriate. The expected costs

should be based on historical costs to develop similar technologies and discussion with entrepreneurs or industry experts.

- Program managers should balance the prize purse with the potential market value of the prize technologies and other benefits that the competition may offer to participants. Low barriers to entry and public exposure for prize entrants are powerful incentives as well.
- The cash reward will ultimately depend upon the authorization and appropriation given to each agency for the prize and the authorities upon which government agencies could rely to structure their own prize competitions.

### **Defining Who Is Eligible to Participate**

Sponsors decide who is eligible to enter and participate in their prizes. In government prizes, agencies must first define whether the prize is open to, for example, the agency’s employees and contractors, or to international entrants as well. In addition, agencies may define a target community or types of entrants that should be engaged in the program.

The sponsors of the three prizes considered in this study set different requirements of eligibility. For example, the Ansari X Prize was open to any private team (including international teams), with the condition that its vehicle had to be privately financed and built. Similarly, neither U.S. government organizations nor organizations principally or substantially funded by the federal government were eligible to enter in the NGLLC. U.S. government employees were not eligible to participate. The DARPA Challenges allowed participation of federal government organizations only when it was consistent with applicable statutes and allowed participation of state and local government organizations. Team leaders were required to be U.S. citizens or permanent residents.

The DARPA Challenges’ open approach to applications was complemented by a rigorous selection process comprising several stages. Entrants were required to prepare technical papers and demonstration videos and allow the sponsor to visit their workplace to assess their capabilities and goals. Only 15 out of 104 applicants qualified to participate for the competition day in 2004, and only 11 out of 89 applicants qualified in 2007.

This experience also demonstrated that competitions with a larger number of entrants are more competitive and therefore more exciting. For example, the 2005 DARPA Grand Challenge attracted 195 applicants (including from 3 high schools and 35 universities), and the 2007 DARPA Urban Challenge attracted 89 applicants. The Ansari X Prize officially included 26 teams from seven countries, but in fact received many more inquiries from potential entrants interested in participating (Maryniak, 2010). The NGLLC enrolled just 12 unique teams, but several of them participated more than once in the four years of competition. The number of participating teams by year was: four in 2006, eight in 2007, nine in 2008, and three in 2009.

Despite the capacity of prizes to attract participants, prize entrants exert widely varying amounts of effort. For instance, most of the NGLLC entrants developed technologies and flew a vehicle for the competition. However, in the Ansari X Prize, only three teams out of 26 performed some kind of test flight, and only two teams scheduled an attempt to win; ultimately, only the winner performed an attempt to win this competition (Kay, 2010). Prize experts understand that serious entrants generally have goals beyond the prize competition as well as access to their own funding (Pomerantz, 2010).

### ***Sponsor Considerations***

- Government prize programs must be fair, transparent, and promote inclusiveness.
- Eligibility requirements should prevent conflicts of interest, reduce the costs of administration, and guarantee that only serious entries are registered for the competition.
- The requirement that competitors prepare technical material or participate in preliminary tests or qualification rounds may be used to lower barriers to entry and guarantee serious entries at the same time.
- Sponsors should maintain an open registration for interested entrants for a reasonable amount of time.

### **Crafting the Prize Rules**

The rules of the prize contain key information about the competition, such as a detailed definition of the prize challenge, the deadline or expiration date, the

eligibility requirements for entrants, and other requirements to comply with existing regulations. These aspects are discussed throughout this report. Maintaining a clear and adequate set of rules is very important for having a successful prize competition. The rules that describe a winning entry are particularly important. While the program manager and his collaborators can design these rules, some technical aspects may require external assistance or consultation with experts.

The managers of the three prizes in this study placed particular emphasis on having a proper set of rules, which must remain unchanged during the competition. The managers made the prize rules publicly available on the Internet. They consisted of a main document, guidelines, and sets of “frequently asked questions” and answers intended to clarify all aspects of the competition.<sup>7</sup> Teams were required to sign sponsor-participant agreements that regulated many matters related to media rights, resolution of disputes, liability, and modification and termination of the agreement. The organizers also appointed judges to select the winning entries and solve potential controversies.

### ***Sponsor Considerations***

- Rules should be kept simple, unambiguous, and easy to understand.
- Rules should remain unchanged once the competition has been announced.
- Prize competitions should be as transparent as possible, i.e. rules should be made public.
- Agencies should work with industry experts, entrepreneurs, and would-be entrants to get further insights to create the proper set of rules.
- Agencies should consider the experience of other agencies in designing rules.
- Agencies should work closely with legal experts to craft sponsor-team agreements and include all the necessary provisions to limit liabilities and comply with laws and regulatory requirements.

### **Securing Program Funding**

The most significant cost of implementation of a prize program is, in principle, the cash purse. Administration costs may be significant too depending on the scale of the program, the number of participants, and the



sponsor's approach to implementing the prize. Prize sponsors may use their own funding and/or get financial support from third-parties. Registration fees to enter the competition and media rights resulting from media coverage of prize events may also support the execution of prize programs. Depending on the configuration used to implement the prize, different cost-bearing structures may be utilized.

Recent experiences show how the costs of administration may vary. The total funding available for the DARPA Urban Challenge 2007 was \$24 million: \$12 million for the competition (including \$3.5 million in prizes) and \$12 million in seed funding to support a few qualified teams. NASA took a different approach, which sought to minimize overhead costs and maximize industry investment. Therefore, the agency contributed the cash purse and had the X Prize Foundation administer the NGLLC at no cost to NASA. Northrop Grumman Corp. also contributed some funding to the administration of that prize.

In general, entrants do not receive initial funding from the program, and have to secure their own funding with help of partners, investors, or receiving in kind contributions. Prize sponsors pay only for concrete results. This may induce entrants to pursue innovative forms of organization and approaches to the challenge, but it may also represent a barrier to participation. For that reason, for example, the DARPA Urban Challenge provided seed funding to 11 qualified entrants in the form of a competitive proposal with awards up to \$1 million each, dependent on performance.<sup>8</sup> This helped some of the best performers, particularly those with smaller teams, to remain in the competition (Whitaker, 2010).

In order to have a fair competition and prevent conflicts of interest, prizes may have different considerations regarding the government funding available to entrants. Both the Ansari X Prize and the NGLLC required entrants to be at least 90 percent privately funded and prohibited the use of government facilities unless they were generally available to all entrants. The DARPA Urban Challenge, however, allowed teams to be paid under a government contract and use the program's assets, provided they had the authorization of the program manager. Some of the teams in fact represented major DoD contractors.

Moreover, prizes can seek to create commercial opportunities aligned with the prize technologies to help entrants raise funding. This strategy may successfully interest private investors if the prize is given the proper visibility. However, the pursuit of commercial opportunities sometimes challenges entrants as much as the technology problem posed by the prize (Pomerantz, 2010). Private investor's funding may also be affected by less favorable contexts, such as in times of economic recession.<sup>9</sup> On the other hand, more favorable contexts, such as new prospects for the prize technologies, may make entrants' activities more interesting to investors.

### **Sponsor Considerations**

- Agencies have different authorities available under existing statutes to structure their prize competitions and identify potential sources for funding their program. Some agencies, such as NASA and the National Science Foundation, may receive private contributions for the purpose of funding prize competitions.
- Agencies may need to request authority to partner with outside entities such as foundations and non-profit organizations for them to award cash prizes to winners of government competitions.
- Agencies should consider third-party organizations to administer the competition at no cost to them.
- Program managers should seek to align the prize challenge with potential commercial opportunities to facilitate entrants' fundraising. Depending on the preferred scheme to fund the prize program, agencies may explore hybrid prize configurations that provide seed funding to participants.
- Agencies should secure the prize purse funding before the announcement of the competition.

### **Assigning Intellectual Property Rights**

The scholarly literature generally considers that prizes are superior to other R&D incentives when they place the intellectual property (IP) rights to the winning entry into the public domain, allowing the adoption, diffusion, and improvement of the prize technology. However, in practice, prize sponsors may relinquish IP rights to entrants to allow the

## Policy and Legal Considerations

Designing prizes and rules that comply with the corresponding legal and regulatory framework is essential. All government prizes, including federal prizes, need to comply with state and local laws as well.

Technology research and development requires participants to abide by existing regulations. However, they may well also have to undertake activities that are not yet regulated and imply risks for health, third-party property, or the environment. For example, the Ansari X Prize and the NGLLC required entrants to obtain special permits from the U.S. Federal Aviation Administration to launch and fly experimental aircraft. Scaled Composites, the winner of the Ansari X Prize, was issued the world's first license for a sub-orbital manned rocket flight.

On March 8, 2010, Jeffrey D. Zients, Deputy Director of Management, issued a Memo (M-10-11) to the heads of executive departments and agencies providing guidance on the use of prizes.<sup>10</sup> The Memorandum highlights the policy and legal issues related to the implementation of the Obama Administration's commitment to increase the use of prizes and challenges as tools for promoting open government, innovation, and other national priorities. Prize-related legal issues include:

- **FACA compliance.** The Federal Advisory Committee Act (FACA) imposes requirements related to certain groups formed to advise agencies. If groups are put together to judge and select prize winners, agencies must comply with FACA.
- **Ethical issues and federal endorsement of products or services.** Any competition, challenge, or contest run by or with the involvement of a federal agency must be run so as to ensure participants are treated equally and there is no conflict of interest, or appearance of a conflict, on the part of the contest judges or administrators.
- **Compliance with state law.** Agencies should evaluate the need for potential contests and prizes to comply with varying state laws.
- **Standard requirements for procurement contracts, grants, and cooperative agreements.** Agencies that enter into procurement contracts, issue grants, or enter into cooperative agreements regarding prize competitions should consider standard requirements for documentation, reporting, and audits, and the Bayh-Dole Act.
- **Paperwork Reduction Act.** Agencies should evaluate the applicability of the Paperwork Reduction Act to any prize-related activities.
- **Privacy Act.** Agencies should evaluate the applicability of the Privacy Act to any prize-related activities.

pursuit of commercial opportunities and promote entrepreneurship.

In the aerospace and defense prizes considered in this study, sponsors generally allowed participants to retain the ownership of their technologies with certain conditions included in the competition rules. For example, the participants of the NGLLC could retain the IP rights on their technologies, provided they agreed to negotiate in good faith with the federal government the granting of those rights at reasonable compensation, if the government chooses to pursue such a license. In the DARPA Urban Challenge, entrants that received seed funding retained the rights to their technologies, but also gave the U.S. government a non-exclusive license to inventions.

Other rights such as trademarks and media coverage rights may require different assignment to properly communicate the program goals and advances and

increase the visibility of the prize competition. For example, DARPA reserved the right to photograph and shoot video of the vehicles and team members, make them publicly available over the Internet, and publicize the prizes. The NGLLC also required participants to agree that the X Prize Foundation, the administrator of the competition, would retain all media rights related to the challenge.

### **Sponsor Considerations**

- Agencies should allow prize entrants to retain the IP rights of their technologies and solutions and agree to enter in good faith negotiations with participants in case the agency is interested in licensing the technologies.
- The sponsor and/or administrator of the competition should maintain the media rights so that they may promote the program and make it visible.

## Implementing the Prize

The implementation of the prize is the actual execution of the competition or prize stage. It requires attention to numerous factors such as collaborations and partnerships with organizations involved in the program, announcement of the prize, administration of the competition, selection of the winning entry and final award, and use of the results. Each of these elements is presented in this section as recommended steps for designing a successful prize program.

### Seeking Collaborations and Partnerships

Depending on their experience and the scope and scale of their prize programs, sponsors may collaborate and partner with external individuals and organizations at different stages of the prize program. This allows access to existing expertise and resources, reduces project risks, and increases the program's impact. In the case of government prizes, agencies can play different roles in designing and implementing the program, as explained in the following examples.

In the design stage, all three sponsors of the aerospace and defense competitions consulted with industry experts and entrepreneurs to define the prize challenges and obtain support for their initiatives. In the implementation stage, the sponsors took on diverse roles. For example, NASA initiated the program and contributed the prize purse of the NGLLC, but used a "hands-off" implementation approach by which the competition was administered at no cost to NASA by the X Prize Foundation.

The DARPA Challenges were initiated, funded, and administered by DARPA with support from consultants and the collaboration of other organizations on aspects such as the preparation of courses and final events. Agencies may also initiate prize programs with private individuals or corporate sponsors. For example, the NGLLC had Northrop Grumman as a co-sponsor. The Ansari X Prize was initiated and implemented by the X Prize Foundation with the sponsorship of the Ansari family, from Dallas, Texas, which ultimately gave the name to this competition.

### Sponsor Considerations

- Agencies should investigate the advantages of collaboration specific to their own sectors in order to draw upon the best internal and external resources.

- Programs initiated by agencies and administered by allied organizations can use more specialized resources with prize expertise to reduce program costs and risks.
- Programs initiated and implemented by agencies allow more control of the whole process and are more likely to promote organizational learning.

### Announcing the Prize and Making It Visible

The resources and timing with which a prize is launched can significantly influence the results of prize programs. Sponsors generally seek to use all the available resources to make a "big splash" with the announcement, promising an exciting competition and seeking to engage both potential entrants and broader audiences as well. The public relations effort thus becomes a key element of a successful program.

The prizes analyzed in this report captured much attention from the public and potential entrants due to their unique features and the fact that no other similar prize initiatives existed at the time. The Ansari X Prize engaged a broader, global audience, thanks to the participation of international teams and the implications of realizing private human spaceflight. That competition was officially announced at the St. Louis Science Center in Missouri with the support of different space organizations, the presence of about 20 astronauts including the Apollo 11's Buzz Aldrin, and the endorsement of the NASA administrator. In spite of that initial public relations effort and subsequent efforts, the characteristics of this competition made it impossible to know where and when a team would attempt to claim the prize, thus affecting media engagement. This kind of problem did not exist in the NGLLC and the DARPA Challenges, which were held at pre-specified sites and were open to the public. They were also very exciting competitions and attracted thousands of people to their final events.

### Sponsor Considerations

- There is not a single method to determine the right moment to announce a prize.
- Agencies should announce prizes after all aspects of prize design have been carefully studied, the prize purse funding has been secured, and the interest of potential entrants has been gauged.



- Program managers should watch industry and broader trends to anticipate favorable contexts and how the competition may be influenced by external factors.
- Care should be taken to maintain the incentive power of prizes, which may be diluted if similar prizes are simultaneously announced or technologies linked to the prize challenge become available.
- Program managers should take advantage of related public events and think strategically to increase the program's visibility and reach out not only to those that may eventually enter the competition, but also to broader audiences including policymakers and the general public.
- Program managers should consider using the online platform Challenge.gov, available at no cost to them, to launch competitions.

### Managing the Competition

The sponsor, or the administrator chosen for the competition, must continually assess the activities of the participants and the feedback provided by them during the execution of the program in order to anticipate potential problems and maintain an exciting competition with the engagement of the media and the public.

In these three competitions, various steps were taken to get feedback from participants and maintain public engagement. Workshops, meetings, and informal interactions allowed participants to exchange opinions and learn about potential problems. For example, the DARPA Urban Challenge held a public conference and webcast with potential entrants to discuss all aspects of the competition and receive suggestions. During the competition, partial milestones and classification rounds were also used to monitor the performance of the teams and assess the efficacy of the program. Teams also used these intermediate milestones to evaluate their own performance.

When the public can watch and follow a prize, it is inherently more exciting both for the participants and the spectators. To make this possible, each of the three competitions appointed media relations managers and created websites with information about the prize, news releases, and profiles of the participant teams. This is particularly important in

competitions that are not held at a pre-specified site or do not include a competition day, such as the Ansari X Prize.

In competitions like the NGLLC in 2006 and 2007 and the DARPA Challenges, a more open format allowed for greater public involvement. The final events of those competitions were held at a pre-specified site, were open to the public, and attracted thousands of people interested in seeing the teams compete. The NGLLC 2008 was webcast over the Internet. Interestingly, prize entrants also contributed significantly to the promotional effort by blogging and publishing other online media about their activities and participation.

### Sponsor Considerations

- Program managers should consider the resources needed to assess the performance of participants, obtain their feedback, and maintain public engagement. For example, regular meetings or more informal phone or e-mail surveys may be used to gather feedback and other information about the teams during the competition.
- Classification rounds (in which teams have to achieve certain standards of performance to classify and continue the competition) may be used to evaluate the overall performance of teams and, if necessary, reprogram further steps.
- Program managers should develop online communities to engage the public using the agency's own Web-based platform or third-party social networking services such as Facebook or Twitter.
- Agencies should assign the necessary staff to manage activities and interact with teams, the media, and the general public, in coordination with other participating organizations.
- When the competition is held on a competition day, sponsors should motivate teams by allowing them to exhibit their technologies in public view.

### Selecting a Winner and Awarding the Prize

Determining a winner is a very important part of the prize program. Ideally, prizes have to select a winner to be able to inspire the public and be regarded as a successful program. Award ceremonies are both the formal recognition of the achievements of the winner, and an opportunity to further communicate

the achievements of the program and demonstrate the transparency of the prize process. There have been cases in which no participant met the technology performance requirements or claimed the cash purse before the prize expiration. Such prize programs may nonetheless have significant outcomes.

The three aerospace and defense prizes were mostly successful in selecting their winning entries, with the exception of the DARPA Challenges in 2004, in which no team met the challenging technology requirements of the competition. This program was still considered successful due to the level of engagement of researchers and students, among other participants, to address a very challenging goal (DARPA, 2006). The winners of these prizes were clear to both the organizers and the public.<sup>11</sup> These two competitions held award ceremonies with the presence of the winning teams, the agency's authorities, government and corporate officials, the media, and the public.

### ***Sponsor Considerations***

- Agencies should define simple and transparent criteria to select the winning entry and appoint objective and independent judges for the competition.
- The winning entry should be obvious to the public and it should be a fair recipient of the award.
- The awards ceremony should include the program's stakeholders and should be used to communicate the results of the program and next steps.

### **Utilizing the Results of the Competition**

Prize competitions may result in technical innovations valuable to the sponsor even when programs are not aimed at developing specific technologies. Depending on the assignment of IP rights, the sponsor may license the technologies or further develop them with more traditional means such as contracts or grants. Program managers should be aware that participants' entries may range from the obvious to the very creative, and may include experimental technologies that are not ready for immediate use. Only multi-year competitions make technological products more predictable when they have returning participants that work on converging solutions over time.

The sponsors of the three prizes did not directly adopt the technologies that emerged in their competitions, but did pursue further development in some cases. Though the Ansari X Prize did not seek to develop any specific technology, winning the prize required a creative approach to building and operating a space vehicle with a relatively low budget. After several years of development, Scaled Composites, the winner, devised an innovative spacecraft with a novel pivoting wing system. The X Prize Foundation has used the worldwide exposure gained with this prize to find new partners, create new prizes, and position itself as a leader in the creation and implementation of prize competitions.

The NGLLC sought to accelerate the commercial development of vertical take-off and landing vehicles with rapid turnaround. The 2006 NGLLC, for example, allowed only about four months for technology development between the prize announcement and the competition event. New startups entered this competition and, throughout four years of competitions, introduced incremental yet significant technological developments in the form of new components, subsystems, standards of operation, speeds of development and efficiency (NASA, 2009). After further development of the technologies, NASA awarded Masten Space Systems and Armadillo Aerospace, the winning teams, \$475,000 to perform test flights of their experimental vehicles under the Commercial Reusable Suborbital Research Program (NASA, 2010).

The DARPA Challenges allowed DARPA to push the envelope of the development of autonomous vehicle capabilities. The prize attracted the attention of companies and other research organizations that may eventually supply these technologies to DoD or participate in other programs for further development. The competitive environment created with the participation of technology leaders in this area led to breakthrough advances in short lead times. DARPA also continued collaborations with some former teams and pursued further developments with technology procurement and defense contracts (Whitaker, 2010).

### ***Sponsor Considerations***

- Agencies should consider their interest in the potential technology outputs when designing the prize. If there is interest in adoption of the

technologies, a proper assignment of intellectual property rights should be made in the sponsor-team agreements to allow, for example, licensing or public disclosures.

- Agencies may award contracts to the winner or to runners-up for further technology development.
- Other follow-up collaborations with former participants may help to prepare the technologies for commercialization.
- Agencies may use the momentum, exposure, and experience gained with the prize program to announce new prizes or implement other programs that draw on the problem-solving community formed by the competition.

## Evaluating the Prize

The evaluation of the prize program, which is the post-prize stage, seeks to measure the effectiveness and efficiency of the program according to its goals. This report has focused on four main impacts and potential contributions of innovation prizes to fulfill an agency's mission: technology development, R&D investment, entrepreneurship, and S&T awareness. In any of these dimensions, a prize program will be effective when it has the intended effects and will be efficient when those effects are accomplished with a minimum use of resources. Those effects may take place during the competition and/or after the program was executed. Analysis of recent experiences has shown that further work is needed to improve the methods used to evaluate government prize programs.

## Defining Criteria for Evaluation

Innovation prizes are not the best policy approach in all circumstances and their impacts should be evaluated considering the potential contributions of this type of instrument.

The three aerospace and defense prize programs all had ambitious goals in the technology development, R&D investment, entrepreneurship, and S&T awareness dimensions, albeit with different focuses. In addition to other more specific goals, the Ansari X Prize focused on changing public opinion about the possibilities of the aerospace industry, while the DARPA Challenges focused on developing the capabilities of autonomous vehicles to operate safely. The

NGLLC focused on the commercial development of rocket technologies.

Different program evaluation criteria were used in each of the case study programs. For example, media coverage and public engagement were measures of effectiveness for the Ansari X Prize. At the time it was won, this competition received more than five billion media impressions and was telecast and webcast to a global audience with the support of NASA, America Online, the Discovery Channel and other media outlets (Maryniak, 2005).

The operational capabilities of the participant vehicles were a measure of effectiveness in the DARPA Challenges. All but one of the entries of 2005 surpassed the maximum distance covered by the best entry of 2004, and the number of vehicles that successfully completed the course went from zero in 2004 to six in 2007, with increasing levels of difficulty in terms of required capabilities (DARPA, 2008).

In the NGLLC, the engagement of entrepreneur teams and their accomplishments have been also measures of success. Most of the teams were new entrants to the aerospace sector; most of them tested vehicles during the competition; and some even went on to further develop their experimental technologies with NASA.

These prizes have also been regarded as efficient programs due to their ability to leverage funding. For example, in the Ansari X Prize, a \$10 million cash purse induced more than \$100 million in R&D activities (XPF, 2004). In the NGLLC, a \$2 million cash purse induced an estimated \$20 million and 100,000 person-hours in R&D (Courtland, 2009). An overall program comparison also shows how the technologies developed for the NGLLC had only one-third of the costs of similar technologies developed for the Delta Clipper program in the 1990s (Pomerantz, 2007).<sup>12</sup>

These prizes also had other less expected impacts and spillover effects. For example, Scaled Composites, the winner of the Ansari X Prize, signed a \$250 million contract with Virgin Galactic to deliver a fleet of spacecraft for suborbital travel (Linehan, 2008). The DARPA Urban Challenge captured the attention of automakers interested in the same technology for civilian use (DARPA, 2008).

## Developing Metrics for Evaluating the Prize

Prizes may encourage diverse technological innovations from the time they are announced to long after the competition has ended. Thus, the ultimate impacts of a prize program, some of which may be unexpected, may not be observable until several months or years later. The implications for prize program evaluation are twofold: first, multiple and diverse metrics should be used to evaluate programs; and second, there should be multiple evaluation points in the program timeline, which will vary depending on the program.

Below are examples of different types of metrics that agencies should consider in evaluating their prize programs. In developing metrics, program managers need to define the appropriate time horizon for the metrics based on the characteristics of each prize program.

In developing metrics for investment leverage, program managers should consider that these are typically fuzzy and difficult-to-measure concepts in the context of prizes. Moreover, prizes may also induce more R&D activity by organizations not officially registered for the competition in the form of follow-up investment and post-prize achievement of prize entrants (e.g. new contracts, new funding).

Category	Metrics (Examples)
<b>Technology achievements</b>	<ul style="list-style-type: none"> <li>• Number and quality of the ideas or solutions contributed by all teams</li> <li>• Novelty and affordability of the solutions</li> <li>• New performance records set</li> <li>• Time required to produce the winning entry</li> <li>• Number of prize entrants that schedule or perform an attempt to win the prize or qualify for a final event</li> <li>• Whether the program finds a prize winner</li> <li>• Diffusion, introduction, or commercialization of the technical solution</li> </ul>
<b>Investment leverage</b>	<ul style="list-style-type: none"> <li>• R&amp;D expenditures by prize entrants</li> <li>• In-kind contributions received by entrants</li> <li>• Working hours spent by entrants</li> </ul>
<b>Prize participation</b>	<ul style="list-style-type: none"> <li>• Number of consultations by potential entrants</li> <li>• Type and number of officially registered entrants</li> <li>• Number of volunteers, students, and independent inventors engaged</li> <li>• Number of organizations that partner with prize entrants (e.g. schools, universities, companies)</li> </ul>
<b>Entrepreneurship</b>	<ul style="list-style-type: none"> <li>• Number of new startups created to enter the competition (prize startups)</li> <li>• Number of prize startups that get financial support to compete</li> <li>• Number of prize startups that continue their activities beyond the prize deadline</li> <li>• Number of prize startups that commercialize their technologies</li> </ul>
<b>Science and technology awareness</b>	<ul style="list-style-type: none"> <li>• Number of courses created in schools on topics related to the prize</li> <li>• Number of schools and students involved</li> <li>• Number of research programs reoriented to pursue challenges similar to the prize</li> <li>• Masters or Ph.D. theses focused on prize programs</li> <li>• Expressions of interest of companies in prize technologies</li> </ul>
<b>Public engagement and perception</b>	<ul style="list-style-type: none"> <li>• Number of people attending competition events</li> <li>• Number and type of media appearances of the program</li> <li>• Overall media impressions</li> <li>• Number of people registered in the prize's online community</li> </ul>
<b>Overall program success</b>	<ul style="list-style-type: none"> <li>• Total cost of technology development and investment leverage compared to similar programs</li> <li>• Whether the prize program received additional funding (the ultimate measure of success from the agency's projects portfolio perspective)</li> </ul>

# Conclusions

## Innovation Prizes as an Alternative Policy Instrument

Prizes are an alternative policy instrument to promote technological innovation and pursue other goals to advance the agency's mission. Prizes are not suitable for all purposes, and a successful competition requires that many parameters are properly set. Table 2 presents a list of factors necessary for a successful prize program. The Appendix shows a summary of recommendations for the use of innovation prizes.

Prizes imply more uncertainty in terms of program outputs and outcomes than traditional instruments, yet their expected payoffs are likely to be higher when they are properly designed and implemented. In general, though competitions may involve the potential duplication of R&D efforts, they can also lead to new approaches and fresh ideas, and bring new individuals and organizations to engage with science and technology innovation. Prizes can also reduce the bureaucratic and accounting barriers that accompany typical grant and contracting processes.

This report looked at the Ansari X Prize, the Northrop Grumman Lunar Lander Challenge, and the DARPA Grand and Urban Challenges, all considered successful programs and valuable sources of experience for program managers. The differences in how the prizes were implemented are instructive. The Ansari X Prize was a privately-sponsored, long-term prize that sought to accomplish goals that exceeded technological development. The NGLLC and the DARPA Challenges were short-term, government-sponsored prizes that sought to accelerate commercial development and create research communities for specific technologies, respectively. From

the point of view of their sponsors, while the Ansari X Prize was the most important (and the only) program of the X Prize Foundation for several years, the NGLLC and the DARPA Challenges represented only a small part of the program portfolio of NASA and DARPA, respectively. This report has sought to provide lessons and recommendations based on these prize experiences, not only for aerospace- or defense-related programs, but for other technology areas as well.

Agencies should use innovation prize-based programs to complement other traditional programs or as an experimental initiative. In general, prizes should be considered:

- When programs imply high-risk R&D
- When innovative or unconventional approaches are needed
- Whenever it is possible to draw upon external resources to advance the agency's mission

Prize programs may be aimed at developing specific technologies or pursue other goals to advance the agency's mission, including entrepreneurship, commercialization, and science and technology awareness, among others. When focusing on technology development, prizes should target early stages of R&D in which exploratory work, faster development, and innovation at the system level are required.

Agencies that have already implemented prizes have learned significantly from the experience, but the overall experience with government prizes is still relatively minimal. Some prize programs have been more successful than others and some prize ideas have not even reached the stage of design or implementation. In general, successful programs have been



**Table 2: Recommended Checklist for Prize Design, Implementation, and Evaluation**

Prize Design	
✓	<b>Prize challenge</b> that is exciting, ambitious yet doable, clearly defined and easy to communicate, sufficiently vague as to allow innovation and creativity, and preferably, aligned with commercial opportunities
✓	<b>Cash purse</b> that covers only part of the expected costs of technology development and is balanced with commercial opportunities and other non-monetary benefits of the competition
✓	<b>Prize rules</b> that are simple, unambiguous, transparent, easy to understand, and comply with existing regulations
✓	<b>Scheme to finance program costs</b> that considers existing authorities and possible alternative funding from private sources
Prize Implementation	
✓	<b>Proper use of collaborations and partnerships</b> with individuals and organizations to design, implement, and evaluate the program
✓	<b>Strategic prize announcement</b> that reaches out broader audiences and makes the prize visible
✓	<b>Proper plan of action</b> to manage the competition, gather feedback from prize entrants, and maintain public engagement
✓	<b>Simple and transparent criteria</b> to select the winning entry and objective and independent judges for the competition
Program Evaluation	
✓	<b>Proper evaluation plan</b> to assess effectiveness and efficiency of the program
✓	<b>Evaluation metrics</b> such as technological achievements, investment leverage, prize participation, entrepreneurship, public perception, program continuation, and other outcomes

based on meticulous work in all stages and posed challenges that were exciting for both entrepreneurs and the general public. These programs have also been more or less aligned with commercial opportunities for prize entrants and have had transparent prize rules. Their sponsors have sought collaboration in all stages of the program and worked on making the prize visible and on engaging the public.

## Key Factors to Increase Program Impact

The following is a list of key factors and recommendations to increase the impact of prize programs. These are articulated in general terms so as to be applicable to a broader range of types of prizes and technologies.

- Focus on designing the appropriate prize.** Successful prize programs require significant effort to define exciting and feasible goals, understandable and simple rules, and complete plans for implementation and evaluation. Program managers have to be prepared for
- contingencies and external factors that may affect the prize outputs and later outcomes. Prize implementation is a learning process for entrants as well as the sponsor. Experienced managers strongly recommend carefully planning the prize parameters and not changing the prize rules after they are announced.
- Define an exciting, ambitious, yet doable prize challenge.** Prizes should be challenging yet represent feasible goals within existing technological capabilities. Most importantly, sponsors should address technological problems that are apparent to the layman, and focus on system-level solutions. Prize challenges should be technologically sound but also fun for the public to watch.
- Collaborate and form partnerships.** Prize sponsors should promote collaboration inside and outside the program, seeking partners to manage the competition or private sponsorships to finance the program and reduce its risks whenever possible. Sponsors should promote the formation of a community and create

instances of collaboration between teams to reduce duplication of R&D efforts. They should respond to the feedback provided by the teams and the public to improve the prize program.

- **Seek to be inclusive and encourage diversity.** Program managers should seek to attract all types of entrants, be accessible to diverse groups, lower funding requirements, and evaluate the potential entrant effect (how attractive the competition is for potential entrants and how likely they are to enter) before announcement. Registration fees may help to attract only serious entries and generate some income as well.
- **Promote the program in the public sphere.** The public relations effort is a key component of successful prize programs. Announce the prize and make it visible, reach out to the public, disseminate and share information with the media to increase the program's visibility and engage potential entrants and the public.
- **Learn from experience.** Prize administrators should look in more detail at past and ongoing prize competitions, and get advice from other agencies or private organizations with prize expertise. Sponsors should seek external insights to define the challenge, the reward, and the rules when necessary. When there is no prize experience, sponsors should start with low-scale and short-term prizes.

## Other Considerations for Aerospace and Defense Prizes


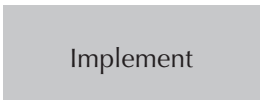
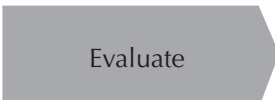
Prizes are only one of many alternative approaches to technology and innovation policy in the aerospace and defense sectors. Still, they may offer significant advantages over other approaches if they are properly designed and implemented. For example, the aerospace and defense sectors typically present higher barriers to entry for students, entrepreneurs, and independent inventors. Prizes may offer concrete opportunities to those groups to get hands-on experience and work on alternative solutions to actual technological problems. That broader engagement represents new ideas and more resources to support the sponsor's mission, but it will not always be available to agencies. Strict safety requirements and expensive or specialized R&D facilities may increase the entry barriers to those

groups and even to traditional researchers and industry players.

Aerospace- and defense-related prize programs may focus on developing technologies for civilian use to advance the agency's goals, by promoting industrial research and the formation of problem-solving communities that may eventually contribute new methods or forms of R&D organization with aerospace and defense applications.

Finally, agencies are encouraged to consider the regulatory framework specific to these sectors and work with legal experts in the design of prize programs, particularly when the prize involves technologies that may be considered inherently military in nature. U.S. citizens and organizations that enter in prize competitions to develop certain aerospace and defense technologies may need to abide by the International Traffic in Arms Regulations (ITAR) and other related regulations. Program managers should explore special eligibility requirements for prize entrants and competition rules that regulate the use or destination of prize technologies in those cases.

# Appendix: Summary of Recommendations for Use of Innovation Prizes

<b>Complement existing programs</b>	<b>Agency's mission</b> ▼ <b>Other Programs</b> ▼	Examples of program technology goals: <ul style="list-style-type: none"> <li>• Explore technologies that imply high-risk R&amp;D.</li> <li>• Explore new approaches to break critical barriers.</li> <li>• Develop cheaper or better solutions with existing technology.</li> <li>• Accelerate application, diffusion, or commercialization.</li> <li>• Raise public or industry S&amp;T awareness and change beliefs.</li> </ul>	
<b>Add value in all stages of the prize program</b>	<div style="text-align: center;">  <p>Design</p> </div> <p><b>Pre-Prize</b> 6–12 months</p>	<div style="text-align: center;">  <p>Implement</p> </div> <p><b>Competition</b> Short-term: 12–18 months Long-term: 24+ months</p>	<div style="text-align: center;">  <p>Evaluate</p> </div> <p><b>Post-Prize</b> Time horizon based on prize goals</p>
<b>Design, implement, and evaluate meticulously</b>	<ul style="list-style-type: none"> <li>• Define an exciting, ambitious, yet doable prize challenge.</li> <li>• Balance cash purse with commercial opportunities and other non-monetary incentives.</li> <li>• Craft simple, unambiguous, transparent, and easy-to-understand rules.</li> <li>• Consider existing authorities and possible alternative financing options.</li> <li>• Consider IP rights and use of prize technologies.</li> </ul>	<ul style="list-style-type: none"> <li>• Collaborate and partner to design, implement, and evaluate the program.</li> <li>• Announce the prize and make it visible to reach broader audiences and engage potential entrants.</li> <li>• Manage the competition, get feedback and maintain public engagement.</li> <li>• Set a simple and transparent criteria to select the winning entry.</li> <li>• Utilize the results of the program.</li> </ul>	<ul style="list-style-type: none"> <li>• Evaluate the program during the competition, immediately after, and in the longer-term.</li> <li>• Apply metrics such as technological achievements, investment leverage, prize participation, entrepreneurship, public engagement, program continuation, and other outcomes.</li> </ul>
<b>Learn from experience and improve your program</b>	<p><b>Key factors to improve program efficiency:</b></p> <ul style="list-style-type: none"> <li>• Focus on designing the appropriate prize.</li> <li>• Define an exciting, ambitious, yet doable prize challenge.</li> <li>• Collaborate and partner.</li> <li>• Seek to be inclusive and encourage diversity.</li> <li>• Find the “right place in the public.”</li> <li>• Learn from the experience.</li> </ul>		

Source: Author's analysis and sources cited in text



# Endnotes

1. Ansari X Prize's official website: <http://space.xprize.org/ansari-x-prize>
2. Northrop Grumman Lunar Lander Challenge's official website: <http://space.xprize.org/lunar-lander-challenge>
3. DARPA Urban Challenge's official website: [www.darpa.mil/grandchallenge/](http://www.darpa.mil/grandchallenge/)
4. The project "How do prizes induce innovation? Learning from aerospace prize competitions" investigates technology prizes and the means by which they induce innovation. It focuses on three main aspects of these prizes: (1) How prize entrants respond to prize incentives, (2) How they organize R&D activities, and (3) How technology advancement takes place in the context of prize competitions. The project is supported in part by the U.S. National Science Foundation under Grant Number SBE-0965103. Opinions, findings and conclusions or recommendations expressed in this work are those of the author and do not necessarily reflect the views of the National Science Foundation.
5. The rules of this competition required the spacecraft to carry not only one pilot, but also the equivalent weight, and space for two other passengers, anticipating the potential use of the technologies for suborbital space tourism.
6. In the National Defense Authorization Act for Fiscal Year 2001, Public Law 106-398, Congress mandated in Section 220 that "It shall be a goal of the Armed Forces to achieve the fielding of unmanned remotely controlled technology such that . . . by 2015, one-third of the operational ground combat vehicles are unmanned."
7. See, for example, the DARPA Urban Challenge's rules and guidelines online at: [www.darpa.mil/grandchallenge/rules.asp](http://www.darpa.mil/grandchallenge/rules.asp)
8. For this, both federal procurement contracts and Section 845 Other Transaction Authority for Prototypes were used (DARPA, 2008).
9. For example, the economic slowdown after the terrorist attack of September 11, 2001, and the increased risk perceived in aerospace activities due to the loss of the space shuttle Columbia in 2003 may have overshadowed the efforts of the Ansari X Prize's entrants to raise additional funding (Maryniak, 2010).
10. Program managers are also encouraged to read the memo issued by the federal Office of Management and Budget (OMB) in March 2010 with further discussion in this regard (see Zients, 2010).
11. Only some controversy was raised in the NGLLC 2009 after the judges allowed (wrongly, according to some) an attempt on the third day that led to Masten Space Systems' victory (SpaceRef.com, 2009).
12. The Delta Clipper program was first led by the U.S. Department of Defense and then by NASA, with participation of McDonnell Douglas Corporation, to develop an experimental vertical takeoff and landing vehicle.

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Kay has received grants from the U.S. National Science Foundation and the IBM Center for the Business of Government to support his research on prizes. Extensive analysis of prize cases has given Kay significant knowledge of prize design, implementation, and evaluation based on empirical research.

Kay's research at STIP investigates nanotechnology scientific publication and patenting activities by universities, government laboratories, and companies in the U.S., Latin America, and worldwide. Kay's current projects include the analysis of U.S. and global corporate research and commercialization networks and the assessment of the U.S. Nanoscale Science and Engineering Centers (NSEC) program. His work at STIP also includes other research areas such as university-industry linkages with focus on SMEs, technology extension services to support industry, innovation and competitiveness in small open economies, and innovation in Georgia (USA) manufacturing enterprises.

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