An Evaluation of Short Innovation Contest Implementation in the Federal Context

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ABSTRACT

Technologies over the past three decades have democratized the tools of knowledge creation, thus creating increasing communities of innovators outside traditional organizations' boundaries. Cost effective ways of leveraging these innovative crowds can be imperative to creating and maintaining value. One specific way for organizations to tap into this diverse audience is through the use of short innovation contests. The purpose of this thesis is to better understand the application of this strategy as a tool for technology procurement in the context of government.

Through a contest, participants approach a well-defined challenge independently, conducting different experiments to find a solution. The combination of these various "trials" leads to an increased probability for a government agency to find one particularly good, extreme-value solution. Contests can also allow government agencies to engage individuals who are normally unable or unwilling to compete in traditional government contracts, thus alleviating certain imperfections in the competitive market of government contracting.

This open design strategy for procurement is fundamentally different than traditional procurement methods. For this reason, there is inherent uncertainty in the organizational implications contest implementation will have in government agencies which has made program managers hesitant to employ this strategy in their programs.

This thesis sheds light on the cost structure, program management implications, and policy considerations for short innovation contests. An empirical analysis is presented for four short innovation contests used for technology procurement in different government agencies. For each case study, the cost of the contest was compared to traditional procurement and key program management considerations were identified. Additionally, recent policy initiatives passed for prize-based contests were analyzed for their applicability to short innovation contests.

It was found that three of the four contests procured technology solutions for estimated costs of less than half that of traditional procurement methods. It was also found that recent contest policy initiatives were unsuitable for short innovation contests. This thesis provides recommendations for policies appropriate for short innovation contests and considerations that must be made to expand the use of this strategy as a tool for technology procurement in government agencies.

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CHAPTER 1

1 Introduction

"Not all of the smart people work for us."

The above quote is a philosophy coined by Henry Chesbrough to emphasize the growing importance of partnering with knowledge communities outside an organization's boundaries (Chesbrough, 2003). This philosophy is fueled by a recent paradigm shift in the nature of innovation which occurred as a result of the decreasing cost of communication, the increasingly widespread nature of information, and the growing number of educated actors with access to this information. The technologies that promoted this paradigm shift democratized the tools for knowledge creation, allowing individuals with few resources to play significant roles as innovative actors.

For these reasons, organizations must find new ways to partner with innovative communities outside their boundaries through more "open" strategies. This also presents an opportunity for government agencies to engage innovative partners who were previously unable or unwilling to compete for government contracts, thereby preventing perfect competition in government contracts.

The motivation for this research stems from the situational and bureaucratic reasons for imperfect competition in government contracting. These contract inefficiencies are particularly harmful at NASA where more than 80% of budgetary spending is allocated to the procurement process (Government Accountability Office, 2011). Improved competition in government contracting can enable government agencies to identify and procure the most innovative technologies and receive the best possible return on their investment. This thesis presents a specific type of open design strategy, "short innovation contests", as a way for government agencies to alleviate the problem of imperfect competitions for certain technology needs.

Innovation contests have been used throughout history by governments around the world to solve grand challenges. This type of innovation tool was recently brought back to life by the X-PRIZE foundation, whose successes inspired certain U.S. government agencies to launch their own contests to solve grand technical challenges. Today, we have seen these isolated experiments move to a broader contest policy initiative in an effort to expand the use of prize-based contests in government agencies.

The first innovation contests employed in U.S. agencies, including the NASA Centennial Challenges, were incentivized with multi-million dollar prizes and took place over several years. As a result, the contest policy initiatives that followed were influenced by the nature of this type of Grand Innovation Prize (GIP) contest. The topic of this thesis introduces a different type of prize-based contest, the short innovation contest, which can be employed for technology challenges that require less time and resources to develop such as software and digital needs. Short innovation contests can be used by government agencies as an alternative to traditional procurement for such technologies.

While this procurement strategy offers considerable advantages over traditional methods for certain technology needs, program managers are understandably hesitant to engage this method of crowdsourcing. For one, it seems risky to trust a crowd with unknown competencies to fulfill a technical need. There is also inherent uncertainty in the cost associated with this procurement and the processes required for successful implementation.

To shed light on these uncertainties, the following research questions were posed:

1. How do short innovation contests compare to traditional procurement methods from a cost perspective?
2. What are the key considerations made by program managers when using short innovation contests to procure technology?

1.1 Research Agenda

The research agenda for this thesis includes the analysis of four short innovation contests that were used by government agencies as a tool for procuring different technologies. The federal program management teams in these case studies had implemented short innovation contests for the first time and their experiences were documented. The four short innovation contest case studies were analyzed from three different perspectives: cost, program management and policy.

1. First, a cost efficiency analysis was completed for each of these short innovation contests. This was done by comparing the cost of implementing a contest to the estimated cost of procuring the same technology through a more traditional method.
2. Second, the management considerations for employing short innovation contests were identified through interviews with the program management teams. From these interviews, key management challenges and lessons learned were identified.
3. Third, recent contest policy initiatives and their applicability to short innovation contests was explored. Considerations for expanding the use of short innovation contests as a tool for technology procurement are provided.

1.2 Thesis Structure

This chapter provided background information for the topic of this thesis and a general overview of the analyses conducted. The subsequent chapters in this thesis proceed as follows:

- Chapter 2 presents the motivation for this research by describing the reasons for imperfect competition in the market of government contracts and highlights why this is especially a problem at NASA. Previous attempts to alleviate these challenges are outlined and the evidence that these attempts have been ineffective is presented.

- Chapter 3 presents the topic of open design strategies as a way to improve competition in government contracting in certain situations. Background literature on the topic of open design strategies is presented. Different strategies are analyzed in terms of their viability in the NASA context, and one specific open design strategy is selected as the focus of this thesis.
- Chapter 4 describes the selected open design strategy, innovation contests, and introduces it as one potential way to improve competition in government contracts. The history of innovation contests is described, their benefits are explored, and the distinction between GIP contests and short innovation contests is explained.
- Chapter 5 provides a cost efficiency analysis for four short innovation contests. Each case study includes an overview of the contest itself, the costs of implementing the contest, and a comparison of the contest costs to the estimated costs of traditional procurement.
- Chapter 6 highlights the challenges and lessons learned from the federal program managers implementing these short innovation contests for the first time.
- Chapter 7 presents an analysis of the policy framework relevant to procuring technology through short innovation contests. This chapter also outlines recommended policies specific to short innovation contests, considerations required for immediate policy action, and policy considerations necessary to expand the use of short innovation contests in government.
- Lastly, Chapter 8 summarizes the cost, program management, and policy analyses. This chapter also presents suggested future work on this topic.

CHAPTER 2

2 The Problem: Inefficiencies in Government Contracting

This chapter outlines the problem this thesis addresses, presents the ways in which this problem is currently being addressed, and the reasons why these current solutions are inefficient.

2.1 Inefficiencies in the Market of Federal Contracts

Competition is a cornerstone of the acquisition system and a critical tool for achieving the best possible return on investment for taxpayers.
-GAO report July 2010 (Government Accountability Office, 2010)

Goal of Perfect Competition

The solicitation of bids for contracts can be viewed as a market place in which federal agencies are the purchasers of contracts with their own willingness to pay, and contractors are the producers with their own willingness to sell. This thesis research is motivated by the problem of imperfect competition in the market of federal contracts and the inefficiencies that lead to this imperfect competition. This thesis highlights the contract market at NASA because this particular agency is charged with developing innovative technologies that will expand our reach in the solar system and at the same time it spends over 80% of its allocated budget on contracts and the procurement process. (Government Accountability Office, 2011)

The government as a whole allocates over $500 billion to contractors each year. These contracts are governed by policies intended to promote perfect competition among contractors. Such policies can be found in the Federal Acquisition Regulation (FAR) which contains the principle set of regulations that governs the acquisition process for federal agencies. The FAR generally requires the government to conduct all federal procurements under "full and open competition" through the use of competitive acquisition procedures. This is intended to create a competitive market and enable the government to select the most innovative products and services at the lowest prices. (Free Advice, 2012)

Proponents of competition also note that competition helps to curb fraud because it allows for periodic changes in the vendors from which the government acquires goods and services. These changes limit the opportunities for government employees to enter into collusive agreements with their regular suppliers. Procuring technology through fully competitive contracts also promotes accountability by ensuring that contracts are awarded based on their merit instead of relationships between contracting officers and contractors. (Manuel, 2011)

The issue of imperfect competition for federal contracts at NASA may not have been seen as a large problem in the past because they were successfully running the Space Shuttle Program, building the International Space Station, and providing jobs to thousands of employees across the country. But today, the Space Shuttle has been retired, the ISS is scheduled to de-orbit in less than 10 years, and flat budgets are expected for years to come. Because of this, it is important to reanalyze the sources of market failure in the competitive market of government contracts, particularly at NASA.

Situational Inefficiencies

Although the government recognizes the need to promote competition and has introduced policies through the FAR that work toward this, certain case-by-case situational market failures exist that prevent a market of perfect competition for these contracts. These situational exceptions, shown in Table 1 below, could be used by a federal agency as a justification *not* to hold the often timely and expensive full and open competitive process for a contract.

Table 1: Seven Exceptions to Full and Open Competition for FAR Contracts.

1	Only one responsible contractor that can satisfy requirements
2	Unusual and compelling urgency
3	International agreement
4	Industrial mobilization; engineering, developmental or research capability; or expert services (i.e. risk of industry dying out)
5	Authorized or required by statute
6	National security
7	Public interest

One main problem is that while these exceptions are useful in certain conditions, they can be abused in situations where a program office has maintained a strong relationship with a specific contractor over an extended period of time. For example, a program office may lobby for contracts to be awarded to the incumbent contractor without competition, primarily due to their relationship and the contractor's understanding of program requirements. Whether or not an exception is fully justified, exercising these exceptions always presents a risk because without competition there is not a direct market mechanism for setting a contract price and there is no assurance that the most innovative technology available was identified.

A second, similar problem occurs when an agency does hold full and open competition procedures but only receives one bid (laws and regulations do not require agencies to assess the circumstances that led to only one offer being received) (Goverenment Accountability Office, 2011). This could occur because of a strong incumbent, sometimes coupled with overly restrictive government requirements, or vendors forming large teams to submit one offer for broader government requirements, when previously several vendors may have competed (Government Accountability Office, 2010). This situation presents the same risk as the seven exceptions above with an additional problem that the agency incurs the cost of a competitive solicitation without receiving the benefits of competition.

These inefficiencies are having increasing influence throughout all agencies. Across federal agencies, total spending on contracts awarded without competition increased significantly from $73 billion in 2000 to $173 billion in 2008. Dollars allocated to contracts that were open to competition but only received one bid also increased considerably from $14 billion in 2000 to $67 billion in 2008 (Orszag, 2010). This is especially a problem for NASA where more than half of contract dollars are awarded in non-competitive contracts (United States House of Representatives Committee on Government Reform - Minority Staff Special Investigation Division, 2004). Noncompetitive contracts do not allow NASA to adequately find and support the best talent available. For an agency that has been ranked as the "most innovative agency," this is a crucial problem (Lunney, 2011).

Bureaucratic Inefficiencies

In addition to situational factors that occur on a contract by contract basis, bureaucratic and organizational pressures also exist that prevent an environment for perfect competition. These tensions exist due to the bureaucratic nature of government agencies as well as inflexibilities in agencies' internal organizational structures. Tensions such as this can prevent perfect competition in "full and open" competitive contracts, or cause contracts to be awarded under one of the seven exceptions listed previously without justification. The main bureaucratic/organizational tensions are summarized in Table 2.

Table 2: Bureaucratic/Organizational Failures.

1	Revolving Door Politics and Lobbyists
2	Budgetary Political Sustainability
3	Export Control Regulations
4	High Barrier to Entry for Small Companies and New-Comers

Revolving Door Politics

The first tension, revolving door politics, occurs when personnel move between roles as legislators, as regulators, and as employees in the industries affected by legislation and regulation. Most industries hire individuals, known as lobbyists, to represent their interests in Washington, D.C. Also, many of these industries will employ people who have previously worked for the federal government in some capacity. Lastly, space companies that compete for NASA contracts may hire individuals who have held important positions at NASA or elsewhere in Washington, D.C. Such placements become increasingly influential when these companies pour large sums of money into lobbying efforts. These influences can give such companies an unfair advantage when competing for government contracts and therefore prevent perfect competition.

For example, in 2010 Orbital Science Corporation a commercial space company competing for NASA contracts, hired former White House Space Policy Director, Peter Marquez, as Vice President of Strategy and Planning (Cowing, 2010). Also, in 2011 another commercial space company, Virgin Galactic, hired Steve Isakowitz, former Deputy Associate Administrator of NASA, to a lead position (Virgin Galactic, 2011). The incentive to hire individuals who understand government policies is clear, but one could argue that this offers an advantage to certain competitors in the market of contracts, which is likely the point of such placements. However, this also puts smaller companies, with insufficient resources to hire such experienced individuals, at a competitive disadvantage.

American economist, George Stigler cites the different benefits that can be awarded to industries by the state which can be influenced by lobbying efforts. Stigler notes that, "The state has one basic resource which in pure principle is not shared with even the mightiest of its citizens: the power to coerce." Lobbyists at contracting firms want to leverage this power to have contracts awarded in their favor. As an example, another leading commercial space company, SpaceX has spent over $4 million on lobbying efforts since its founding in 2002. SpaceX was selected by NASA as the first commercial provider of transportation to the International Space Station with over $1.6 billion promised in NASA contracts. While SpaceX's technical prowess is undeniable, some have argued that political pressure has played a significant part in SpaceX's successful partnership with NASA (Franzen, 2012).

Budgetary Political Sustainability

Secondly, there is a tension that exists from NASA's need to achieve budgetary political sustainability over time. As a member agency of the American Executive Branch, NASA is subject to political forces. To ensure budgetary political sustainability, NASA must maintain a program's support among the public, within Congress, and other invested stakeholders (The Political Sustainability of Space Exploration, 2008).

American economist and psychologist, Herbert Simon, notes that just as it is assumed in neoclassical analysis of business enterprises that firms act to maximize profit, governments act to maximize political power and bureaucrats act to maximize their chances of survival in office (Rationality in Political Behavior, 1995). This takes effect at NASA because NASA employees are concentrated in different districts across the country and bureaucrats that represent these districts act in a way that maintains their employment. As noted in the paper, "The Political Sustainability of Space Exploration":

> *"Those members of Congress with NASA employees in their districts have a distinct electoral incentive to maintain a domestic human spaceflight capability, namely keeping their constituents employed and maintaining existing revenue streams in their state."*

The incentive to keep congressional stakeholders happy to ensure budgetary political sustainability may encourage NASA to prefer contractors in key districts over other suitable competitors. The flip side of this problem is that contractors are sometimes *discouraged* to compete for NASA contracts due to this political uncertainty, for fear that they will not be able to sustain that revenue stream in the future.

Export Control Regulations
The third tension, control regulations, affects the competitive market of NASA contracts in particular because many of NASA's technologies are protected by the International Trade and Arms Regulations (ITAR). ITAR is a set of import and export regulations that are set in place to provide national security by protecting technologies from getting into the wrong hands. These policies also generally restrict NASA from awarding federal contracts to companies that are comprised mostly of international individuals. This effectively limits the pool of competitors for NASA contracts.

In addition to this, ITAR can inhibit the competitiveness of the contractors themselves because companies working with ITAR technologies are prevented from collaborating with international partners and employing top notch international employees. The internal competitiveness of the individual contractors can hurt the overall competiveness of the contract market. Today, however, ITAR policies are under review and are likely to be revised in the near future (Nichols, 2010).

High Barrier to Entry
Lastly, the FAR itself is an inhibitor to perfect competition because it is seen as a barrier to entry for small companies with limited resources or companies with no previous experience contracting with the government. The FAR contract has become so increasingly complex that companies must hire personnel with expert knowledge of the detailed requirements outlined in the FAR. The FAR's detailed requirements are necessary in certain circumstances to ensure safety in technologies that may have an impact on human life. However, small companies may not have the resources to become familiar with these requirements and larger companies that have never worked with NASA before may not be inclined to do so due to the time and resources required to understand the detailed framework of FAR-based contracts.

A counterargument could be made that it may not even be appropriate to contract certain technologies, such as technologies that require high development resources, to small companies because they could not fulfill the task with limited resources. Therefore, the concept of "perfect competition" may not include the involvement of small companies for all technologies, but may be especially true for technology needs that require a relatively small amount of resources.

2.2 Congressional and Executive Branch Actions

Attempted Solutions

The Executive Branch and Congress have taken actions to address certain market failures that have been described in Section 2.1. These attempts are outlined in Table 3.

Table 3: Attempted Solutions to Correct Market Failures and the Failures they Addressed.

	Attempted Solution	Failure Addressed
Executive Branch	OMB Memo Instruction to Reduce Non-Competitive and Sole-Source Contracts	Situational Failure: *Unjustified Non-Competitive Contracts*
Executive Branch	Office of Federal Procurement Policy requires agency to employ a "competition advocate"	Situational Failure: *Unjustified Non-Competitive Contracts* Bureaucratic Failure: *External Influence*
Congress	Small Business Act	Organizational Failure: *High Barrier to Entry for Small Companies*
Congress	Open Government Initiative	Organizational Failure: *High Barrier to Entry for Small Companies*

As mentioned in Section 2.1, the solicitation of non-competitive contracts had ballooned between 2000 and 2008. Because of this, in 2009 the Office of Management and Budget (OMB) released a memo instructing agencies to reduce by at least 10 percent the combined share of dollars obligated to high-risk contracts (including sole-source and non-competitive contracts) by 2010 (Orszag, 2009). Unfortunately, a review by the Government Accountability Office of the agencies' efforts showed that agencies fell short of this goal, only reducing high-risk contracts awarded by 0.8%. The reduction of non-competitive contracts was slightly more successful with a reduction of 5.6%. However, competitive solicitations receiving only one offer remained relatively flat, increasing by 0.3% from 2009 to 2010 (Government Accountability Office, 2011). While overall, agencies' efforts to reduce sole-source and non-competitive contracts was ineffective, some agency procurement chiefs suggest that the initiative was successful in that it raised awareness about the importance of matching the proper contract type with an agency's mission (Goverenment Accountability Office, 2011).

The second attempted solution listed occurred in May 2007 when the Office of Federal Procurement Policy mandated that the head of each executive agency designate a competition advocate for the agency and for each procuring activity of the agency (Office of Federal Procurement Policy, 2007). The competition advocate must, among other things, review the contracting operations of the agency, submit an annual report on competition to the agency's senior procurement executive and chief acquisition officer, and recommend goals and plans for increasing competition. While this solution also increases awareness about the importance of competition, it is difficult to measure the effect this particular initiative has had on the competitive nature of contracts.

The third attempt referenced to alleviate certain market failures was the Small Business Act which, among other things, set a goal for all federal agencies to deliver at least 23% of prime federal contracts to small businesses. This solution addressed the failure that FAR-based contracts discourage small companies with few resources to apply for such contracts due to the inherent complexity of the FAR. However, while this policy encourages agencies to select small businesses as contract awardees, it does not necessarily enable small companies to obtain resources necessary to cope with the FAR contract.

Additionally, this third policy could have the negative effect of pressuring government agencies to procure technologies to small companies even when they are not the most innovative competitor. The difficulty in finding suitable small businesses to contract with may be seen in the federal agencies' failure to meet this 23% goal over the past six years. In 2007, across all federal agencies, small businesses were allocated only 21.7% of contracting dollars. That may seem very close to the goal, but the difference accounts for nearly $4 billion set aside for small companies (Pagliery, 2012). This policy does not address the root of the market failure which is that small companies do not have the necessary resources or incentives to contract with the government.

The last solution, the Open Government Plan, was an initiative by the Obama Administration which tasked all government agencies, including NASA, to outline their initiatives to increase transparency, participation, and collaboration within their organizations (The White House, 2009). Through the collaborative initiatives in the NASA Open Government Plan, new ways to develop technology have been proposed and piloted including the creation of open source software, easier access to scientific data, and the use of prize-based contests. While these initiatives work to lower the barrier to collaboration with individuals and small companies, they are not allocated significant funding and are only occurring at a few government agencies and at a couple NASA centers. However, the Open Government Plan has started a movement of cultural change throughout government agencies by adding new technology development tools to federal program managers' toolboxes and encouraging them to use these tools. The next chapter will elaborate on this concept of "openness" and different types of open design strategies.

This chapter outlined the attempts to address the problem of imperfect competition in government contracting by Congress and the Executive Branch. While these initiatives have raised awareness about the issue, the weaknesses in these strategies show that more work must be done to improve competition in procuring technologies for government programs.

CHAPTER 3

3 Open Design Strategies

The previous chapter presented the problem of imperfect competition in the market of government contracts. It also showed that the government has recently recognized these imperfections and has attempted to alleviate the problem through a number of actions taken by the Executive Branch and Congress. While these actions have been ineffective in solving the problem, they were useful in that they brought awareness to the issue of imperfect competition.

This chapter introduces the concept of open design strategies, referenced in the previous chapter, as a more effective way to promote competition in the procurement of technologies. "Open design" is presented as an umbrella term that represents different strategies which allow a firm or organization to better leverage external ideas and work performed outside their system. Open designs work off of network based models where there is not necessarily a central hub and most of the activity occurs at the periphery.

This chapter first describes the movement from closed design strategies to open design strategies. The different types of open design strategies are outlined with an emphasis on the different ways organizations can use crowds as an innovation partner. These crowdsourcing strategies are defined and their application in the NASA context is explored.

3.1 History of Open Design

For most of the twentieth century, companies held the view that successful innovation required complete control of their technologies. Top secret research and development was a valuable strategic asset, even a formidable barrier to entry for other competitors. Powerhouses like DuPont, IBM, and AT&T performed the most research and effectively earned the most profits within their respective industries (West). A basic model of closed design is shown in Figure 1.

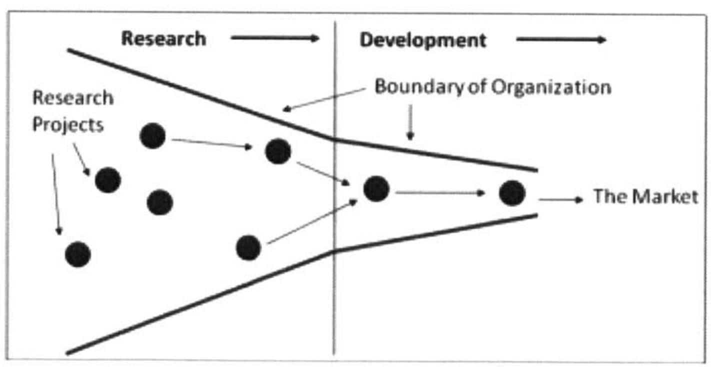

Figure 1: Closed Innovation Model. (Chesbrough, 2003)

The closed innovation model illustrates how a company would invest resources into multiple research projects. As these projects progress from the research phase to the development phase, it would be found that some projects did not fit well with the company's current business model or perhaps were not appropriate for their current target market. These technologies would often be patented, but would ultimately go unused (Chesbrough, 2003).

In the years leading up to the twenty-first century, however, a number of factors led to changes in this paradigm. The first factor involves the increasingly widespread nature of information and the prevalence of "digitization" wherein information and physical products were translated into digital formats (Greenstein, et al., 2010). Even material products can now be translated digitally which enables them to be modified, transformed and created with the same relative ease as software goods (Baldwin, et al., 2006).

The second factor is due to the increased number of individuals with access to such information and at low costs. Increased access to internet and other advanced technologies have democratized the tools of knowledge creation (Lakhani, et al., 2013). Along the same lines, the cost of global knowledge dissemination and coordination has decreased significantly (Benkler, 2006) (Castells, 2000) (Shirky, 2008).

A third important factor was the increased presence of private venture capital which could provide large financial support to small start-ups and transform them into growing, competitive companies. It became increasingly important for previously closed organizations to develop ways to leverage knowledge outside their boundaries.

For these reasons, the locus of innovation began to shift outside the boundaries of the traditional firm (Lakhani, et al., 2013). Henry Chesbrough, who is recognized at the father of open innovation, cites the belief that "not all the smart people work for us" as the key mantra of an open strategy (Chesbrough, 2003). Under an open design strategy, companies will use a more decentralized, more participatory, and more distributed approach to leverage knowledge outside their organization. Similarly, technologies that would have previously gone unused in a closed strategy may be spun outside the firm. The general process of open design is illustrated in Figure 2.

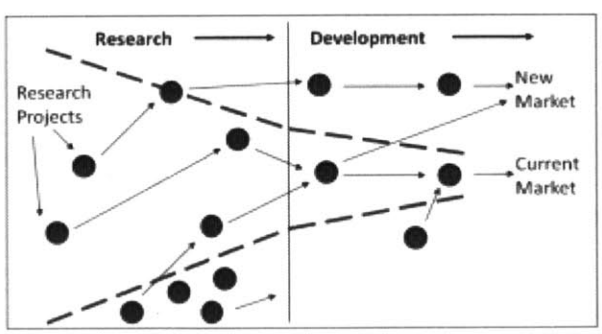

Figure 2: Open Innovation Model. (Chesbrough, 2003)

It is important to note that a company will not typically be completely closed or completely open. It has been argued that organizations need to embrace complex organizational boundaries where firms simultaneously pursue a range of closed and open design strategies. These two strategies are fundamentally different and have contrasting organizational boundaries and processes and will be more or less appropriate for different technologies in different circumstances (Lakhani, et al., 2013).

In organizational economics, the concept of organizational boundaries has been rooted in transaction logic. This literature has focused on the allocation of activities between inside and outside the firm's boundaries. The appropriate allocation of activities, which translates to appropriate organizational boundaries, will be based on minimizing transaction costs and maximizing value to the firm (Salancik, et al., 2003); ("Neither hierarchy nor identity: knowledge governance mechanisms and the theory of the firm", 2001); ("Organizational boundaries and theories of organization", 2005); ('Designing the boundaries of the firm: from "make, buy, or ally" to the dynamic benefits of vertical architecture', 2006); ("Balance within and across domains: the performance implication of exploration and exploitation in alliances", 2011).

In order to create value, organization scholars have noted that an organization must create complex goods and services which requires continuous knowledge creation. (March, et al., 1958); (Chandler, 1977); ("Neither hierarchy nor identity: knowledge governance mechanisms and the theory of the firm", 2001); ("A knowledge-based theory of the firm - the problem-solving perspective", 2004). The requirement of ongoing knowledge development can be very costly. Therefore, cost effective ways of leveraging existing knowledge bases can be imperative to creating and maintaining value.

Today, the cost of communication, innovation, and collaboration with communities outside an organization has decreased significantly. This opens up new opportunities to leverage this vast knowledge base in a cost effective manner. For these reasons, it is imperative that organizations begin to build in organizational structures to allow for innovation through open design strategies.

3.2 Types of Open Design Strategies

The main literature in the area of open design focuses on the concepts of (1) open innovation, (2) collaborative design, and (3) crowdsourcing strategies. Some strategies may be more appropriate in the for-profit context whereas others are better suited for the NASA context. This is because organizations generally tend to allocate their limited resources between processes of creating value (i.e. innovating, producing, and delivering products to the market) and appropriating value (i.e. extracting value in the marketplace) (Mizik, 2002). One key difference between NASA and a for-profit company is that each will focuses their resources differently.

Resource allocation at NASA is primarily influenced by its principal stakeholder, Congress, because Congress determines NASA's budget each year. Congress is primarily interested in the value that NASA provides to the public, the private sector, national security, the scientific community, and the nation as a whole. Because of this, NASA focuses its discretionary spending on projects that will maximize value creation. In contrast, a for-profit company will often create just *enough* value to customers in order to maximize value appropriation (revenue) over time (A Positive Theory of Social Entrepreneurship, 2009). While for-profit companies will focus on commercialization, it is not a priority for NASA. Therefore, the strategic use of open design will differ in each context.

This distinction between the for-profit context and the NASA context can be considered as we explore different options to leverage knowledge outside an organization. This section provides an overview of the three main types of open design strategies and describes their potential application at NASA.

(1) Open Innovation

Henry Chesbrough coined the term "open innovation" in 2003 describing it as "the use of purposive inflows and outflows of knowledge to accelerate internal innovation, and expand the markets for external use of innovation, respectively" (Chesbrough, 2011). Chesbrough emphasizes the requirement of a business model and a market to distinguish open innovation strategies from other open design strategies that leverage external resources. Therefore, this definition primarily focuses on the technology transfer process between companies where a business model is used as the source of both value creation and value capture.

This process of technology transfer may work well in different for-profit firms but it is not a widely used strategy at NASA. This is because NASA works with complex problems that often require unique and highly expensive technology solutions. For example, a heat shield designed to protect multi-million dollar equipment by withstanding extremely high temperatures, high vibrations, and radiation upon reentry into Earth's atmosphere will not likely have many profitable terrestrial applications. While this is an extreme example, the incentive for NASA to focus on value creation and not commercialization when developing technologies limits the benefit of open innovation at NASA.

(2) Collaborative Design

Collaborative design is a strategy that allows for contributions from multiple parties in the form of subsystems to one larger more complex system. System architecture scholars such as Eberhardt Rechtin and Mark Maier have noted that some very large, complex systems like the Internet can only be developed through collaborative design processes (Maier, et al., 2002). The International Space Station is another example where multiple parties contribute subsystems to one larger complex system.

This strategy is useful in situations that require a greater amount of resources than NASA can provide by itself. This is the case in large scale projects like the International Space Station. But due to the amount of overhead associated with this scale of collaboration with NASA, this strategy is not cost effective or timely for the vast majority of NASA's technology needs.

(3) Crowdsourcing

There are instances where certain challenges can be tackled by partnering with the crowd as an innovative partner. Crowds offer the benefit of scale and diversity which can be difficult to match through other innovative strategies (Boudreau, et al., 2013). Boudreau and Lakhani outline four different types of crowdsourcing strategies which include: (a) Complementors, (b) Labor Markets, (c) Collaborative Communities, and (d) Contests. This section will first provide an overview of each crowd-sourcing method and then present a table outlining their applicability in the NASA context.

(a) Complementors

Crowd complementors involve creating a platform on which third party developers can build upon. Crowd complementors leverage innovation from the user who will each perceive a technology in their own way and will innovate to serve their own personal needs. Economist Eric von Hippel notes that in this type of innovation, the user only has one market to serve and therefore has few creative restraints (Postrel, 2005).

(b) Labor Markets

Crowd labor markets are employed when there is a need for repetitive tasks which require human intelligence for which it would be difficult and expensive to hire full-time employees. Such tasks could include labelling unique features in images, simple data entry, and cleaning data sets. This strategy has also been applied to more complex jobs by creating a community where those with jobs come together with skilled workers. Job-owners can incentivize a crowd of skilled workers to bid for jobs through payment of completed work. This has been done on platforms such as Elance, oDesk, and Short Task (Boudreau, et al., 2013).

(c) Collaborative Communities

Crowd collaborative communities are designed to leverage and organize work from multiple contributors into a coherent value-creating product. Examples of collaborative communities include Wikipedia and Linux open-source operating system. Organizations must create a structure to organize these efforts, but collaborative communities work best when users can accumulate, recombine, and share ideas freely (Boudreau, et al., 2013).

(d) Contests

Innovation contests have become increasingly popular as a new tool to open up problems to a broader solver base. An innovation contest is a problem solving process that discloses details of the problem at hand and invites participation from anyone who deems themselves qualified to solve the problem (Jeppersen, et al., 2010). Participants are often incentivized to submit high value solutions with prizes offered for the best submissions. This strategy has been employed at a grand scale with multi-million dollar multi-year contests run by the X-PRIZE foundation and more recently at a smaller scale through software-based contests run by the challenge platform TopCoder.

Crowdsourcing Applications at NASA

Table 4 compares the four different crowdsourcing strategies defined above and describes their potential applicability at NASA.

Table 4: Crowdsourcing Strategies and Their Potential Applications at NASA[1]

	Purpose	Application at NASA
Complementors	Encourage innovation by providing a core platform on which third party developers can build upon.	This type of strategy can be effective when there are market incentives for third party developers to innovate – iPhone apps, for example – and the sponsoring organization has a mechanism in place to capture this value. However, the uniqueness of NASA technologies means that the incentive for third parties to innovate in relatively limited. Additionally, because NASA is primarily focused on value creation as opposed to technology commercialization, there may be a discrepancy in technology goals between NASA and third party developers.
Labor Markets	Effectively and efficiently match skilled workers with appropriate tasks.	This strategy has been employed through a project called NASA ClickWorkers where public volunteers identified and classified craters on images of the surface of Mars This project attracted more than 80,000 people who identified nearly 2 million craters (Szpir, 2002). While project proved effective in this instance, the amount of effort required to organize and manage contributions makes this strategy difficult to apply to a diverse range of technology needs.
Collaborative Communities	Organize and aggregate a large number of diverse contributions into a cohesive, value-creating product.	NASA has piloted this strategy through the use of open source software with the goal of increasing the quality of NASA software by peer review (NASA, 2003). But similar to the barrier of crowd complementors, the uniqueness of NASA technology and software applications limits the incentives the general population has to work with the technology or software. Additionally, intellectual property cannot be protected. For these reasons the applications for collaborative communities at NASA may be limited.
Contests	Identify novel solutions through large scale experimentation incentivized by competition and prizes.	Innovation contests can be applied to a large scale and variety of NASA technology needs. Innovation contests are similar to complementors and collaborative communities in that an organization will make a technology design or set of information open to the public. With contests, however, the innovation is now guided by the challenge owner. Additionally, contests overcome the challenge of a lack of market incentive associated with complementors by incentivizing users to innovate through the use of prizes and competition.

[1] Table adapted from Boudreau et. Al "Using the Crowd as an Innovation Partner," HBR 2013.

These four crowdsourcing strategies can be used by an organization to partner with a crowd in an effective way. While each strategy described has the potential to provide value to NASA for certain technology needs, contests are likely the most effective way for NASA to leverage crowd-derived innovation for the largest range of technology needs. Contests provide external incentives that may be lacking in crowd complementors and collaborative communities. Contests can also allow the contest sponsor to control the intellectual property which is not the case in collaborative communities. Additionally, contests may be implemented by NASA to fulfill a more diverse set of technology needs than either open innovation or collaborative system design.

Short innovation contests can improve the competitive nature in the procurement of certain technologies for two main reasons. For one, few resources are required to participate in a short innovation contest. This lowers the barrier to partnership such that individuals, small companies and newcomers can participate in government programs. Therefore, short innovation contests can engage a broader pool of diverse actors than can be achieved through traditional procurement methods.

Secondly, submissions to these contests are graded anonymously and often through an automatic scoring mechanism which is not generally the case in traditional procurement methods. By engaging a larger pool of diverse actors and grading submissions anonymously, short innovation contests are argued to alleviate imperfect competition in the procurement of certain government technologies.

For these reasons, this thesis focuses on the applicability of short innovation contests as one possible approach to alleviating the market failure of imperfect competition in government contracting, especially at NASA. The next chapter describes the history, use and benefits of innovation contests in the government context, and explains the difference between Grand Innovation Prize contests and short innovation contests.

CHAPTER 4

4 Innovation Contests

The previous chapter outlined the different types of open design strategies that have been extensively reviewed in literature and how these strategies fit within the context of government, specifically at NASA. Different crowdsourcing strategies were explored and their potential to address NASA technology needs was discussed. It was argued that NASA can more effectively engage knowledge communities outside their organization to work on a larger range of technology needs through innovations contests than with any other open design strategy.

This chapter further explores innovation contests as strategy to solve technology challenges. First, the history of innovation contests is presented. Next, the incentives that motivate solvers to participate in contests are explored and the benefits of employing this type of strategy specifically in the government context are explained. Lastly, this chapter presents the range of innovation contests currently in use and introduces the type of prize-based contest analyzed in this thesis: short innovation contests.

4.1 History of Innovation Contests

Challenging crowds to compete to find a solution by providing prize incentives has been used throughout history in various industries. This strategy has been employed by both for-profit and government organizations who seek innovation in technology, product design, art, manufacturing, and marketing and advertising, among others areas.

One of the earliest examples of prize-based innovation contests occurred in Florence, Italy in 1418 for the design of what ultimately became known as the Duomo. The construction of the Duomo, which was designed to be the largest dome in the world at the time, began 140 years prior to the competition. It was left unfinished because it was found to be impossible to create a dome over such a large space using the architectural techniques at the time. Therefore, in 1418, the Wool Merchant's Guild, the largest, wealthiest and most powerful guild in Florence, offered a commission of 200 florins to a designer who could finish the job. Ultimately, the contest was won by the famous architect and engineer, Filippo Brunelleschi (Brunelleschi and the Creation of Il Duomo, 2006).

In 1714, the British government offered up to 20,000 pounds for a simple method that could accurately determine a ship's longitude. The main winner was John Harrison, a clockmaker that developed an improved clock design called a marine chronometer that could be used to accurately determine a ship's longitude (Sobel, 1995).

Prizes can also be found throughout the history of the aerospace industry, even before the Wright brothers' first powered flight. In 1901, Alberto Santos-Dumont won the 100,000-franc Deutsch

Prize by flying an airship 6.8 miles around the Eiffel Tower. After that time, the British Daily Mail used prizes in more than fifteen different aviation contests between 1906 and 1930 which lead to the first transatlantic flight by John Alcock and Arthur Whitten Brown (Warwick, 2013).

More famously, in 1919, a New York hotel owner, Raymond Orteig offered $25,000 to the first aviator to fly non-stop from New York City to Paris or vice-versa. Several well-known aviators attempted this feat but the prize was ultimately won by the relatively unknown American, Charles Lindberg in his aircraft, the Spirit of St. Louis (Check-Six, 2012).

A more recent example of a successful contest program implemented in the aerospace sector is the Ansari X-PRIZE competition. This contest offered a ten million dollar prize for the first non-government organization to build a spacecraft capable of carrying three people to an altitude of 100 kilometers twice within two weeks (X-PRIZE, 2004). Twenty-six teams from seven countries spent more than $100 million toward the pursuit of this prize (Pomerantz, 2006). Ultimately the challenge was won by famed aerospace designer Burt Rutan and his company Scaled Composites. X-PRIZE has since scaled this competition model to challenges in the area of energy and environment, ocean exploration, education and global development and life sciences.

Inspired by the successes of the X-PRIZE contests, select government agencies have employed their own grand challenges. NASA was one agency that led the way in piloting these Grand Innovation Prize contests through the NASA Centennial Challenges program. Through a handful of Centennial Challenges, NASA has spurred innovations in a range of domains including astronaut gloves, small satellites, and lunar rovers (NASA, 2013).

4.2 Incentive Structure of Innovation Contests

Intrinsic and Extrinsic Motivators

Previous research on contributors to open source software, which is similar to innovation contests in that participants have been given design information and voluntarily choose to submit innovations, has shown that the incentives that drive participants to contribute innovative solutions can be surprisingly heterogeneous. While one obvious motivator is the prize purse, there are a number of other extrinsic and intrinsic motivators that incentivize participants to submit innovations. Figure 3 shows that the wide range of motivations found can mostly be divided into extrinsic motivations and intrinsic motivations.

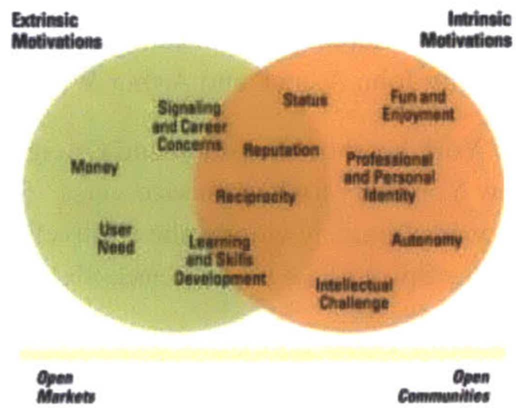

Figure 3: Motivations for Open Source Software Contributions (Boudreau, et al., 2009).

Simple extrinsic motivators include prizes offered for each competition. These prizes can take many forms which can include monetary awards, intellectual property awards, or other physical prizes and recognitions. In addition to prizes, solvers may directly benefit from the solutions they create.

Some contributors may be motivated by purely intrinsic incentives. Edward L. Deci and Richard M. Ryan, professors in the Department of Clinical and Social Sciences in Psychology at the University of Rochester, define intrinsic motivation as "the doing of an activity for its inherent satisfaction rather than for some separable consequence" (Richard, et al., 2000). Fun and enjoyment from participation, or even the learning aspect of developing a solution have been cited as motivators for participants. Lastly, ranking high as a solver for a particular challenge may provide status, identity, and contribute to an individual's reputation as a problem solver in a particular field and could be used to signal one's talents to potential employers (Lakhani, et al., 2003).

Community / Competition Based Motivators

Emerging challenge platforms like TopCoder depend on a community platform of "solvers" to compete to solve technical challenges. The creation of these solving communities can trigger obligation based motivations (Lindenberg, 2001). The goal for the participants within the community is to act consistently within the norms of a group. This obligation is strongest when the need to gain personal advantage at the expense of other community members is minimized (Lakhani, et al., 2003). However, in contest communities, participants can both collaborate and share their knowledge with other community members while also competing against them. Contest communities both promote and benefit from simultaneous incentives motivated by cooperation and competition ("Communitition: The Tension between Competition and Collaboration in Community-Based Design Contests", 2011).

While competition in itself can be a powerful motivator, more competition does not necessarily translate to increased motivations for participants. In an analysis of more than 9,000 TopCoder contests, Boudreau et al. found that innovation outcomes declined when more individuals competed. Greater rivalry reduces the incentives of all contest participants to dedicate effort toward their submissions. Boudreau et al. refer to this as the "incentive effect". At the same time, adding competitors to a contest, each pursuing independent approaches or "parallel paths" can increase the likelihood that at least one participant will submit an extreme-value solution. This is known as the "parallel path" effect ("Incentives and Problem Uncertainty in Innovation Contests: An Emperical Analysis", 2011).

Boudreau et al. also found that increased rivalry has a smaller impact on the maximum performance under certain circumstances. A *positive* parallel path effect from adding competitors existed in multi-domain contest problems where there was great uncertainty in the skills required and/or type of approach necessary to solve the technical challenge at hand. There was also a reduced *negative* incentive effect from adding competitors in multi-domain contest problems.

Importance of Motivation Considerations

Each of these motivators should be considered when using a contest to drive innovation. The level of effort required by the participant to submit a solution should be balanced with the level of intrinsic and extrinsic motivators provided for that participant. If the level of effort required to submit a solution for the contest outweighs the level of motivations, very few participants will submit solutions. If the level of motivations outweighs the level of effort required, resources are likely being wasted. Also, if the prize amount is *too high* for a contest, some participants may incorrectly perceive the difficulty level of the contest and be too intimidated to participate. Optimizing the prize purse, while outside the scope of this research, is certainly an important step in achieving the critical balance between participant upfront cost and participant motivations.

Consideration of tradeoffs between the parallel path effect and the incentive effect is important when determining when to close contest participation. Contests around multi-domain problems, meaning the problem could likely be solved with approaches from multiple domains, are likely to benefit from contests where participation is open and many solvers are permitted to compete. In contrast, contests around single-domain problems are likely to benefit from contests that limit participation such that the incentive for participants to exert effort and make investments is optimized.

4.3 Benefits of Innovation Contests

A prize-based contest is an attractive incentive mechanism because it allows a contest sponsor to attract many diverse actors to their specific problem. Publicizing contests through challenge platforms such as TopCoder, Innocentive, or Kaggle allow an organization to tap into a large community of "solvers" that are traditionally outside the reach of the contest sponsor.

During a contest, a relatively large number of individuals are approaching a well-defined challenge independently, conducting different experiments to find a solution. The combination of these various "trials" leads to an increased probability of a contest sponsor finding one particularly good, extreme value solution (Boudreau, et al., 2011).

Innovation contests can offer unique advantages over traditional internal methods of technology procurement. While internal development may be desired when the technology need is fully understood, contests can provide considerable advantages in cases where the technology, design, and innovation approaches have yet to be established (Boudreau, et al., 2009). For government agencies, contests can also offer the additional benefit of promoting public challenges and engaging and educating a large number of citizens.

Commonly cited benefits of contests specifically from a government perspective (Deputy Director for Management, OMB, 2010) include the ability to:

1. Stimulate private sector investment that is many times greater than the prize itself.
2. Increase the number and diversity of the individuals and organizations addressing a particular national or international issue.
3. Establish an important goal without having to select a specific approach or individual that is most likely to succeed.
4. Award prize money *only* if the contest goal is achieved.
5. Improve skills of participants in the competition.
6. Further an agency's mission by enlisting public participation around a defined program goal.

In reference to the first benefit outlined, others have pointed out that from an economic perspective, some contests may be considered to be socially wasteful specifically *because* they stimulate private sector investment many times greater than the prize itself (Lakhani, 2010). This is more likely in a Grand Innovation Prize contest which offers prizes in the millions and takes place over a number of years. Sometimes the goal of such a contest is to stimulate the creation of a new industry. However if the goal of a contest is primarily for technology procurement, as is the case in short innovation contests, it is crucial that contest sponsors take into consideration the cost assumed by participants.

For NASA, prize-based contests could be used as a strategy to incentivize a knowledge base outside of NASA's current reach to participate in NASA programs. As explained in Chapter 2, due to the upfront cost required to navigate NASA's acquisition process through FAR-based contracts, small companies and newcomers experience a large barrier to partnership with NASA (Winkle, 2012). By employing prize-based competitions, NASA can lower the barrier to collaboration and partner with individuals who previously did not have the resources to work with NASA. Because this engages more of the American public in NASA's missions, it can also help garner more public support which will in turn help satisfy the needs of Congress (The Political Sustainability of Space Exploration, 2008).

While contests can offer government agencies a desirable alternative to traditional strategies for innovation and technology procurement, there are organizational and program management challenges related to implementing this new innovation model. Chapter 6 addresses certain key challenges experienced by program managers implementing this innovation tool for the first time and offers insight into ways these challenges can be overcome.

4.4 Types of Innovation Contests

Prize-based innovation contests are applicable to a wide range problems and challenges. Each challenge will require participants to invest a certain level of time and resources in order to compete. This level of effort required will determine where a contest falls along the spectrum between short innovation prize-based contests and grand innovation prize-based contests.

MIT professor Fiona Murray defines Grand Innovation Prize (GIP) contests as ones that require significant commitment and breakthrough solutions that are awarded with large monetary prizes. The primary example of GIP contests are X-PRIZE competitions that typically offer prizes on the order of $10 million through contests that take place over the course of multiple years and require significant investments from participants (Grand Innovation Prizes: A Theoretical, Normative, and Empirical Evaluation, 2012). The purpose of a GIP contest is not generally to procure a good or service for the prize-sponsor, but rather to incentivize innovation in a specific area in order to stimulate the creation of a new market.

GIP contests can be contrasted with short innovation contests which have relatively small prize amounts and run a few weeks in length. This type of contest is appropriate for problems that require minimal effort from participants and can be innovated on quickly such as software or algorithm based challenges. In contrast to a GIP contest, the purpose of a short innovation contest is generally to procure a specific good or service.

Private companies have emerged as "challenge platforms" to help firms and government agencies design and run short innovation contests. These challenge platforms offer years of contest design experience to organizations seeking to implement a contest into their programs. Hosting a contest on one of these platforms also provides a challenge owner access to that specific platform's "solvers" – individuals from around the world who have registered on the site to compete in contests. The platform TopCoder organizes a community of over 470,000 solvers from around the world, making it the largest competitive community for software development and digital creation (2013).

This thesis focuses on the analysis of government-sponsored short innovation contests in the software and algorithm domain run on the TopCoder platform. Case study analyses for these contests are presented in the next chapter.

CHAPTER 5

5 Case Study Examples

The previous chapter introduced the concept of short innovation contests and described how government agencies can use this tool to tap into a large number of diverse participants external to their organization. This chapter presents four case study examples of short innovation contests used in the government contest run through the NASA Tournament Lab (NTL) which is a joint partnership between NASA, Harvard Business School and TopCoder. NTL works with government organizations to host contests on TopCoder so that real-world contests can be analyzed to refine the science of how to successfully design and implement prize-based contests.

Analysis

This chapter describes and analyzes four short innovation contests in the software domain organized by NTL and run on the TopCoder platform. Data for this analysis was obtained through interviews conducted with NTL, TopCoder, and the federal program managers involved in designing the contests. Through these interviews, the following information was collected:

(1) The *cost* associated with contest design and operations, which is presented in this chapter.
(2) The *program management considerations* made while working through this new business tool, which is summarized in Chapter 6.

Cost Accounting Process

The cost of running a short innovation contest has been broken down into three main sources of costs shown in Table 5 as: challenge posting fees, labor fees, and the prize purse. Challenge posting fees and labor fees make up the upstream costs while the prize purse is attributed to the downstream cost. This distinction becomes important when comparing the costs of contests to those of traditional procurement.

Table 5: Main Sources of Contest Costs.

Upstream	(1) Challenge Posting Fees (2) Labor Fees
Downstream	(3) Prize Purse

Challenge posting fees are the fees that TopCoder charges for hosting the contest and their consulting services. Labor fees are identified using labor hours reported by NTL and the contest owner and multiplying these hours by burdened hourly labor rates. The prize purse for a given challenge may be given as one sum to one individual or it can be awarded to multiple solvers who submit top solutions. The prize purse can also either be awarded once at the end of a competition or broken down and awarded at different phases of a given contest. While prize purses and challenge posting fees can generally be considered as flat rates, the cost of labor will depend on the hours worked per individual throughout the lifetime of the contest.

It is difficult to compare the cost of the case study contests to historical examples due to the small sample size of contests used as a procurement strategy. Because of this, the evaluation of the contest costs is based on cost avoidance, meaning the estimated cost avoided by selecting a contest over a traditional procurement method. Cost avoidance is determined by comparing the cost of the contest to the cost of obtaining that same technology through the traditional method of hiring a contractor or developing that technology internally. The cost of a traditional procurement method is described here as a cost counterfactual.

The individuals who provided estimations for the case study contest costs can be found in Appendix I.

Creating Cost Counterfactuals

The counterfactuals in this analysis were designed to compare the costs of obtaining the technology through a contest to those of procuring a comparable technology with a contractor or with an internal team. Due to the uncertain nature of the solution ex ante, this cost avoidance method was more appropriately applied after the contests were completed and the solution was known. The upstream costs for procurement are incurred through the acquisition process. This process, simplified here, includes: (1) Preparing a public notice of solicitation, (2) Release of public notice of solicitation, (3) Request for proposals, (4) Judging proposals, (5) Selection of top proposals, (6) Acceptance of best and final offers, and (7) Award notice.

Upstream Costs

The costs associated with this traditional acquisition process should be compared to the upstream cost of a contest which includes the challenge platform fees and the labor fees. That being said, however, it can be very difficult to estimate the acquisition (upstream) cost for theoretical proposals. The work required to prepare for a contest will overlap with much of the work required to prepare a traditional Request for Proposals (RFP). There is much uncertainty on the amount of overlap that exists. Some argue that most or all of the upfront work for contests is also required for traditional procurement, while others argue that the uniqueness of contests leads to more upfront work than for traditional procurement.

For this analysis, the upfront cost of traditional procurement through a contract was estimated by speaking with acquisition experts at NASA. Acquisition costs for contracts less than $1M were estimated to be between 10% – 20% of the contract cost, which is the downstream cost. For the case study cost counterfactuals in this thesis, a percentage between this 10% - 20% range was selected based on the estimated level of effort required to prepare for an RFP.

Downstream Costs

Next, the prize purse (downstream cost) should be compared to expected contract cost estimated to develop a comparable technology. This cost can be estimated by requesting quotes from contractors with relevant experience. Alternatively, the contest downstream cost could be compared to the estimated cost of developing the same technology in-house.

Each case study below describes the problem that the contest was addressing, an overview of the contest itself, a cost analysis summary, and a counterfactual comparing the cost of the contest to the estimated cost of a more traditional procurement method.

The individuals who provided estimations for the case study counterfactuals can be found in Appendix I.

5.1 Longeron Shadowing Contest

Problem Definition

The International Space Station cost NASA over $50 billion to design and construct and is used today as a test bed for conducting experiments in the unique environment of weightlessness (Minkel, 2010). To support these experiments and maintain general use of the ISS, power is supplied by eight solar arrays which are held to the space station by long thin beams called longerons. The configuration of the solar arrays can be changed in order to maximize power to the ISS. One main limitation in maximizing power is the fact that temperature gradients along the longerons can cause these longerons to bend or even break. To optimize power generation from the solar arrays, the arrays must be oriented in such a way that maximizes direct sunlight along the solar panels while minimizing uneven shadowing along the longerons.

NASA had worked on this technical challenge for five years until a sufficient solution was identified in 2008. While the problem was technically solved, it was not optimized for maximum power generation. More power generated would allow a higher number of experiments or potentially higher power experiments to be conducted on the ISS which can help NASA better their return on investment. For these reasons, NASA launched a contest on the TopCoder platform challenging programmers to come up with an algorithm that optimized power generation while minimizing longeron shadowing.

Contest Overview

The NASA ISS Longeron Shadowing Contest challenged participants to identify optimal positions of the ISS in its orbit around the Earth in order to maximize power under specific constraints. In order to do this, a computer-aided design (CAD) model that specified the simplified geometrical model of the ISS needed to be developed. NASA had possessed a detailed ISS model which had been used by their contractor, Boeing, to analyze all configuration changes made to the ISS. However, due to the precision inherent in the Boeing model, running each participant's submission through this model would take too long to use practically for a contest. Therefore, an initial TopCoder contest was held to create a less detailed ISS surface model which would provide sufficient precision for the challenge but also run quickly enough to analyze submissions from hundreds of competitors.

From this ISS surface model contest, a CAD model was identified that could run each participant's solution in less than 15 seconds. TopCoder participants were challenged to use this surface model to determine the angular position and velocity of each joint that controls the solar arrays. This had to be done for each minute of the ISS's 92 minute orbit with the goal of achieving maximum average power generation.

The contest ran for three weeks, offered a total prize purse of $30,000, and attracted 4,056 TopCoder registrants. Ultimately, 2,185 submissions were received by 459 unique competitors.

The submissions were judged based on the average power output over six key beta angles (the angle between the ISS orbital plane and the vector from the center of the sun). Eight small cash prizes (<$1,000 each) were awarded as milestone prizes throughout the contest. Once final submissions were in, ten larger cash prizes (<$10,000) were awarded for top solutions. The winning solution provided an average power output of 156.9kW. Under the current ISS configuration, the average output over the same beta angles was around 90kW.

However, upon verifying the winning algorithms using Boeing's high-precision ISS model, discrepancies were found in the power output values. One particular problem was that most submissions produced significantly lower power outputs on average; much lower than 156.9kW. Also, some of the lower ranking submissions in the contest produced higher power outputs than the top ranking submissions under the high-precision ISS model. It was clear that the contest model had a few bugs and required refining.

Due to the inaccuracies in the contest model, the TopCoder submissions were not by themselves able to be implemented by the ISS team. The ISS contest model needed to be refined. Through a peer review process on the ISS contest model, a few bugs were identified. After fixing these bugs, the top solutions were re-run and the average output was found to be around 92kW. This is slightly higher power output than what is currently achieved by the ISS team. The challenge owner noted that these were promising results that would move the ISS team closer to optimization and that follow-up contests could be used to refine and improve upon top solutions.

Cost Summary

Costs are broken down into (1) Challenge Posting Fees - TopCoder, (2) Labor Fees – NASA ISS Team and NASA Tournament Lab, and (3) Prize Purse. The *upstream costs* here are the challenge posting fees and the labor fees, while the *downstream cost* includes the prize purse. The TopCoder fees are accounted for within the challenge posting fees. The total costs of the contest were estimated to be $110,770. A summary of the total cost breakdown is provided in Figure 6.

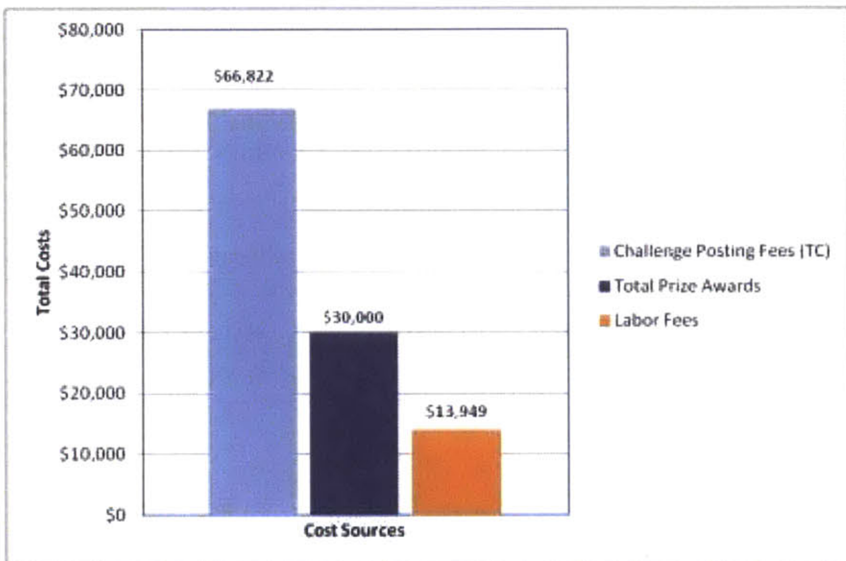

Figure 4: NASA ISS Longeron Shadowing Contest Cost Overview.

The upstream costs contributed to 73% (~ $80,771) of the contest's total costs (TopCoder's challenge posting fees at 60%, and labor fees at a combined total of 13%). The downstream cost contributed to 27% ($30,000) of the total contest costs.

Counterfactual

To analyze the cost efficiency of this contest, upstream and downstream costs of this contest were compared to the upstream and downstream costs estimated to occur if ISS configuration optimization were obtained through the ISS team's prime contractor.

Upstream Procurement Costs:

As noted above, the acquisition cost of traditional procurement makes up the upstream cost which will be compared to the upstream cost of the contest. For the ISS Longeron Shadowing Contest, a simpler surface model needed to be developed that would run through inputs more quickly than the Boeing model NASA currently had. The program manager noted that this would have been necessary for traditional procurement and would have likely been created internally – it would not have been the responsibility of the contractor. Because of this additional work, it is estimated that acquisition cost would be on the higher end of 20% of the contract cost.

Downstream Procurement Costs:

The program manager of this contest provided a quote for the estimated contract cost if his team were to hire their prime contractor to perform a trade optimization study. To procure the same technology acquired through a contest, a six month contract on the order of $200,000 - $300,000 would have been required.

Table 6: Estimated Cost of Traditional Procurement for the ISS Longeron Shadowing Contest.

Contractor	Estimated Contract Cost
ISS Prime Contractor	$200,000 - $300,000

Counterfactual Summary:

The estimated findings for upstream and downstream procurement costs are compared to those found for the NASA ISS Longeron Shadowing Contest in Table 9.

Table 7: Upstream and Downstream Cost Summary for the ISS Longeron Shadowing Contest.

	Upstream	Downstream	Total
ISS Prime Contractor	~$40,000	$200,000 minimum	~$240,000
Contest	$80,770	$30,000	$110,770

The minimum total cost estimated to acquire a comparable solution through traditional procurement methods was found to be about $240,000. Contest total costs were found to be less than half (46%) of this. While the upstream cost of the contest was approximately 200% more than that of procurement, the cost savings were found in the downstream costs where contest costs were roughly 15% that of procurement.

5.2 Crater Detection Contest

Problem Definition

Craters, the most common topographical feature on the moon, provide crucial information to mission planners and scientists at NASA. Knowledge of crater characteristics allows mission planners to determine proper landing sites and helps scientists understand planet formation and geology. Additionally, craters help engineers and scientists align a variety of disparate data sets including radar and laser altimetry to each other (Crusan, 2011). However, there exists an increasing amount of orbital imagery of the Moon, Mars and other planetary bodies, each taken under various illumination conditions and camera poses. For these reasons, it is impossible to characterize each crater manually. Therefore, NASA chose to use the TopCoder platform to find an automatic and robust crater detection algorithm to help solve this challenging data mining problem.

Contest Overview

NASA invited TopCoder solvers to develop an algorithm to detect and measure craters in a given set of orbital images taken under various illumination conditions and camera poses. Participants were given a dataset of more than 200 images of the Moon's surface that each contained multiple craters. An example image can be seen in Figure 4.

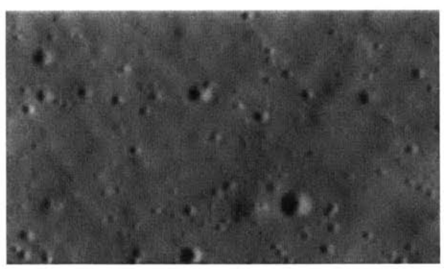

Figure 5: Example Moon Surface Image Given to TopCoder Participants.

TopCoder solvers were given this set of images and challenged to create an algorithm that would report the size and location for craters that fit within a certain size range. The submitted algorithms could then be tested against a different set of images that had been manually labeled through the MoonZoo project.

MoonZoo was a crowd-sourcing project started by the Zooniverse organization that enabled volunteers to participate in scientific research by analyzing images of the Moon. Through this project, participants were given images of the Moon's surface from the Lunar Reconnaissance Orbiter and were asked to help categorize the hundreds of thousands of rocks, craters and other obstacles. Thousands of volunteers generated the labeled images that served as an important input for both creating and testing the software programs developed by TopCoder members.

The contest ran for two weeks, had 1,174 TopCoder solvers register, and 310 unique submitters. The winning solution provided an F1 score (a measure of the algorithm's accuracy where 1 is the best score and 0 is the worst score) of 0.8, which the program manager considered to be sufficient. It was also noted that the TopCoder final solution both complemented and improved the quality of previous solutions developed internally.

Cost Summary

The following cost analysis follows the strategy for cost accounting outlined in the previous section. Costs are broken down into (1) Challenge Posting Fees - TopCoder, (2) Labor Fees – NASA Challenge Sponsor and NASA Tournament Lab, and (3) Prize Purse. The *upstream costs* here are the challenge posting fees and the labor fees, while the *downstream cost* includes the prize purse. The TopCoder fees are accounted for within the challenge posting fees. The total costs of the contest were estimated to be $34,880. A summary of the total cost breakdown is provided in Figure 5.

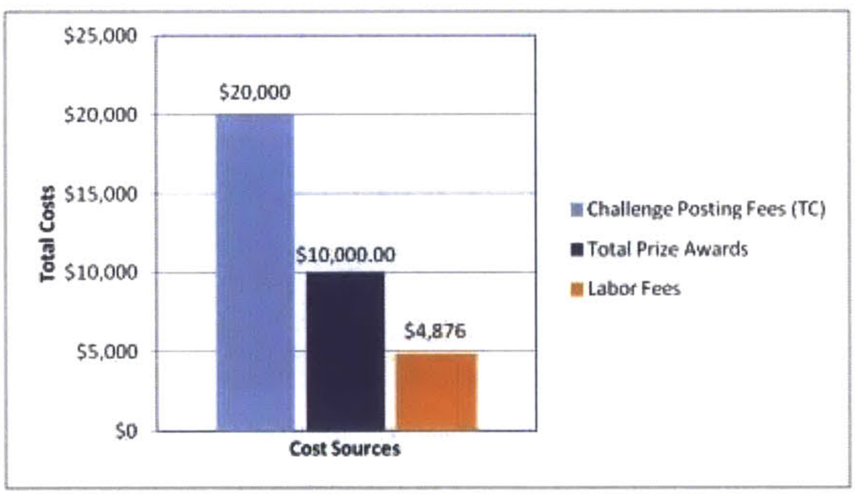

Figure 6: NASA Crater Detection Contest Cost Overview.

The upstream costs contributed to 71% (~ $24,880) of the contest's total costs (TopCoder's challenge posting fees at 57%, and labor fees at a combined total of 14%). The downstream cost contributed to 29% ($10,000) of the total contest costs.

Counterfactual

To analyze the cost efficiency, upstream and downstream costs of this contest were compared to the upstream and downstream costs estimated to occur if an image detection algorithm were acquired through a more traditional method. The program manager for the Crater Detection Contest noted that this product could be acquired by hiring and mentoring an intern for three months of full time work.

Upstream Procurement Costs:
As noted above, the acquisition cost of traditional procurement makes up the upstream cost which will be compared to the upstream cost of the contest. While an official RFP would not be required for hiring an intern, an acquisition cost would still be incurred through requesting and grading internship applications, working through the hiring process, and preparing a general project description. This process is estimated to cost 10% of the cost of paying the intern. It is assumed that most of the preparation required for the developing the solution would have been the responsibility of the intern and therefore no further costs are associated with the upstream cost of traditional procurement.

Downstream Procurement Costs:
As noted above, the program manager stated that an image detection algorithm could be acquired by hiring an intern full time over the course of three months. It was suggested that the intern would have been paid a $10,000 stipend. The manager estimated that he would likely have to spend 20% of his time to mentor the intern which would be equivalent to approximately $8,000 of burdened labor fees. The cost of the intern and the mentorship time required from the program manager would make the downstream cost total to $18,000. We can combine this downstream cost with the upstream cost of 10% of the student's stipend ($10,000) which would raise the total cost to $19,000.

Table 8: Estimated Total Cost for Traditional Procurement for the Crater Detection Contest.

Source	Estimated Total Cost
Intern with Mentorship from Manager	$19,000

Counterfactual Summary:
The estimated findings for upstream and downstream procurement costs are compared to those found for the NASA Crater Detection Contest in Table 7.

Table 9: Upstream and Downstream Cost Summary for the Crater Detection Contest.

	Upstream	Downstream	Total
Intern	~$1,000	$18,000	~$19,000
Contest	$24,880	$10,000	$34,880

The total cost estimated to acquire a comparable solution through traditional procurement was found to be about $19,000. Contest total costs were found to be approximately 1.85 times more than this at $34,880. While the downstream costs of the contest was less than that of traditional methods, the upstream cost of contest design and preparation was significantly more than traditional methods.

Ultimately, the total cost of the contest that produced a sufficient solution was more than the estimated cost of procuring the same technology through traditional means. However, this contest provided other benefits that could not have been achieved through traditional means, including engaging over 1,000 coders from around the world in this specific NASA mission and receiving over 300 unique solutions to this problem. As this was a NASA sponsored problem, engaging the public in a NASA mission through a contest provides important return on NASA's investment. This benefit is not captured in this cost avoidance assessment.

5.3 US Patent and Trade Office Patent Labeling Contest

Problem Definition

The United States Patent and Trade Office (USPTO) has over 8 million patents on file (USPTO, 2011). For a patent to be issued, it must fulfill a number of qualifications, including the condition that the concept has not already been patented. To ensure that this condition is met, patent applications must be carefully reviewed and compared to similar patents already on file. One of the more time consuming tasks for patent reviewers is the process of scrolling through patents to locate figures that are referred to throughout the text. This particular problem inspired the Patent Labeling contest.

NTL, together with USPTO launched the Patent Labeling Contest hosted by TopCoder to develop new algorithms to aid in patent identification. The contest challenged TopCoder participants to develop an algorithm that identified patent figures and figure parts. Contest participants had to make use of text recognition, image analysis, and the construction of bounding boxes to complete the challenge (TopCoder, 2011).

A contest was selected as the tool to acquire the necessary technology for a couple different reasons. First, because an external interest to understand the use and benefits of contests exists, external prize funding was made available to USPTO for this contest. While the prize purse was only a fraction of the contest development costs, this funding helped the program manager to "try out" a contest for the first time. Second, TopCoder allowed USPTO to take advantage of an existing community of "solvers" which was attractive to USPTO. The USPTO Patent Labeling contest was advertised to TopCoder's community of software developers (200,000 at the time of the contest) who compete regularly to solve different types of programming challenges. USPTO was also able to leverage the experience and expertise of TopCoder to develop their first contest.

Contest Overview

The USPTO Patent Labeling Contest invited developers to help solve the problem of text and image recognition within the patent review process. Participants were provided with an image of a patent drawing page, which contained one or several figures. Each figure had a title and consisted of many parts. Each part was labeled with a certain text (typically a number). Some parts had multiple labels. To complicate matters, many drawing pages also included additional data that did not belong to any of the figures. The goal of the challenge was to extract the following data from patent drawing images:

1. for each figure, its location and title;
2. for each part label, its location and text.

The contest was designed to run for four weeks between the end of 2011 and the beginning of 2012. The total prize purse summed to $50,000. $10,000 of this prize purse was provided to top ranking players and is used as the relevant "prize purse" for this initial contest.[2] Additionally, all competitors received a limited edition t-shirt to acknowledge their efforts in participation.

Ultimately 232 teams (463 participants) signed up for this first competition, of which 70 teams (30%) submitted software code. Twenty-nine countries were represented among those participants who submitted solutions. This group of submitters included roughly half (49%) professionals, 39% students, and the remainder reporting not working or part time. The majority of participants ranged between 18 and 44 years old. Seven of the participants were in academia (PhD students, professors, or other research positions). Most (80%) of the non-student participants were self-described software developers of various kinds.

[2] Embedded within this event was a series of social science experiments to investigate different team formation mechanisms. It is estimated that $40,000 of the $50,000 worth of prizes is attributable to the social experiments. The details of that work are beyond the scope of this thesis.

The top solution achieved roughly 80% efficiency in identifying all figure locations and titles and all label locations and text. While this was considered a "success" to the contest sponsor, a follow-up contest was pursued to improve on the top submissions of this contest.

The follow-up contest ran for three weeks, offered $10,000 in prizes and increased the top algorithm increased the efficiency up to 90%.

Cost Summary

Costs are broken down into (1) Challenge Posting Fees - TopCoder, (2) Labor Fees – USPTO and NASA Tournament Lab, and (3) Prize Purse. The *upstream costs* here are the challenge posting fees and the labor fees, while the *downstream cost* includes the prize purse. The TopCoder fees are accounted for within the challenge posting fees. The total costs of the contest were estimated to be $78,250. A summary of the total cost breakdown is provided in Figure 7.

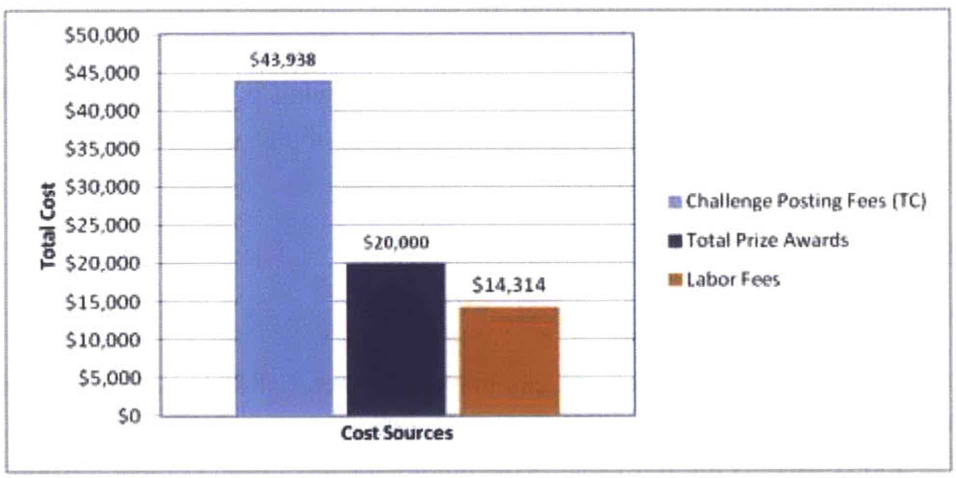

Figure 7: USPTO Patent Labeling Contest Cost Overview.

The upstream costs contributed to 74% (~ $58,250) of the contest's total costs (TopCoder's challenge posting fees at 56%, and labor fees at a combined total of 18%). The downstream cost contributed to 26% ($20,000) of the total contest costs.

Counterfactual

To analyze the cost efficiency of this contest, upstream and downstream costs of this contest were compared to the upstream and downstream costs estimated to occur if a contractor was hired to develop the same technology.

Upstream Procurement Costs:

For the USPTO Patent Labeling Contest, it was predicted that most of the work required to solve the problem would fall under the responsibility of the contractor. Because of this, it is estimated that the acquisition cost would be on the lower end of 10% of the contract cost.

Downstream Procurement Costs:

To estimate the downstream costs, relevant contractors were contacted for quote estimations. A total of six contractors with expertise in image recognition software development were contacted for this project. These contractors were provided with the problem statement of the contest and a thorough description of the problem USPTO was hoping to solve. The characteristics of the winning solution were not made available for reference.

Three contractors responded and only two were willing to provide estimated contract quotes. These estimated quotes are listed in Table 10.

Table 10: Estimated Cost of Traditional Procurement for the USPTO Patent Labeling Contest.

Contractor	Estimated Cost
A	$200,000 - $800,000
B	$150,000

Both Contractor A and Contractor B stated that their expertise could be applied to the USPTO problem statement provided. Contractor A provides software development services to leading technology providers and to end user organizations in need of specialized applications. This contractor stated that to develop a sufficient solution, it could cost anywhere between $200,000 and $800,000.

Contractor B offers software solutions for real-time pattern recognition that can be integrated into various applications. Company B believed that their pattern recognition technology could be easily adapted to solve this problem for around $150,000.

Counterfactual Summary:

The estimated findings for upstream and downstream procurement costs are compared to those found for the USPTO Patent Labeling Contest in Table 11.

Table 11: Upstream and Downstream Cost Summary for the USPTO Patent Labeling Contest.

	Upstream	Downstream	Total
Contractor A	~$20,000	$200,000 minimum	~$220,000
Contractor B	~$15,000	$150,000	~$165,000
Contest	$58,000	$20,000	$78,000

The minimum total cost estimated to acquire a comparable solution through traditional procurement methods was found to be about $165,000. Contest total costs were found to be less than half (47%) of this. While the upstream cost of the contest was approximately 400% more than that of procurement, the cost savings were found in the downstream costs where contest costs were roughly 13% that of procurement.

One could note that the technical solution found within the seven-week time span (including the follow-up contest) was only 90% efficient at identifying the required patent text, images, and labels. However, it was uncertain to the USPTO contest host as to whether industry standards could have performed better than this result.

Certainly a more accurate comparison would be to compare the total contest costs with the cost of procuring an equally efficient solution. However, it is difficult to deduce the level of efficiency that the cited contractors would have achieved in their solutions. This analysis assumes that the quotes from contractors would result in a solution at or near 90% efficiency.

Ultimately, the total cost of the contest that produced a sufficient solution was less than the estimated cost of procuring the same technology. Because of this, it was determined that the USPTO Patent Labeling Contest was a cost efficient method of procuring this specific technology.

5.4 Center for Medicare and Medicaid Services Provider Screening Innovator Contest

Problem Definition

The Center for Medicare and Medicaid Services (CMS) is a federal agency that administers the Medicare program and also works with state governments to administer Medicaid. Medicaid programs have increased in complexity over the years and have become multibillion dollar enterprises in most states. Collectively, Medicaid programs draw more than $180 billion in federal funding each year to local economies (Center for Medicare and Medicaid Services, 2012). Traditionally, states have worked on a "pay and chase" model – where Medicaid routinely pays every bill that comes in and only goes after someone for fraud if it is blatantly obvious that something was wrong (for example, 900 dental procedures in one day). Some estimate that while private insurers lose 1 to 1.5 percent due to fraud, Medicaid programs may be closer to 10 to 15 percent (Merrill, 2012).

For these reasons, the Obama Administration stipulated that states must create a rigorous screening process for providers and suppliers enrolling in Medicare and Medicaid in the Affordable Health Care for America Act (Healthcare.gov, 2011). However, each state has their own Medicaid Management Information System, all of which perform the same function for the most part, but in slightly different ways. Additionally, states do not typically re-use or share services from other states. In an effort to standardize the Medicaid IT system, CMS released the Medicaid Information Technology Architecture (MITA) which provides a common framework for all Medicaid stakeholders to build common and shared services.

CMS, in partnership with the state of Minnesota, launched a contest on the TopCoder platform in order to create an effective screening module that could work on the MITA framework and meet the requirements of the Affordable Care Act.

Contest Overview

The CMS Provider Screening Innovator Contest challenged participants to develop a provider screening software application which would be capable of risk scoring, credentialing validation, identity authentication, and sanction checks.

The submissions were graded on various metrics including their capability to:

1. Conduct identity verification
2. Build provider profiles
3. Evaluate and maintain the integrity of the results
4. Improve easy access to important provider information
5. Integrate into the MITA framework and meet other architectural guidelines
6. Be accurate, cost effective, and timely

The Medicaid office at the state of Minnesota was brought in to provide state-level insight for the design of this contest and to pilot the screening module that resulted. The goal of this contest was to produce a MITA compliant shared service module that would assist states in conducting screening of enrolling providers and revalidating existing providers to determine if providers should become or remain Medicaid providers. Ideally, this module would be implemented in multiple state Medicaid programs to both standardize the provider screening process and avoid the cost of states creating their own unique screening modules.

The CMS Provider Screening Innovator Contest comprised of a series of over 140 contests over the course of eleven months. A series of contests such as this is a useful contest strategy for complex problems that require modularization into many smaller problems in order for the final result to provide value. Each contest would validate, analyze or build on the results of the previous contests.

In assessing the resultant product from the CMS Provider Screening Innovator Contest, the program management team identified the main strengths and weaknesses of the final product, which are outlined in Table 12.

Table 12: Major Strengths and Weaknesses in the CMS Provider Screening Innovator Contest Solution. (Center for Medicare and Mediaid Services, 2013)

Strengths	Weaknesses
The system met the majority of the requirements defined for the project.	The artifacts created through the contest process were highly fragmented and contain significant redundancy, making them time consuming and difficult to comprehend.
The system scored highly in the goals of reducing the cost, and improving the accuracy, consistency, and timeliness of provider screening.	The lack of documentation provided for different parts of the system create a barrier for reuse in state programs.
The system features an easy to use web interface that is modular.	
The level of automation provided in provider screening makes the system a tremendous improvement over manual methods currently used across the country.	

While the final product scored well in meeting the requirements established for the contest and improving the process of provider screening, the end result was highly fragmented, had many redundancies and was difficult to understand. For these reasons, the final product as-is would be very difficult for another state to adopt without significant effort to understand the system and modify it for their specific business processes.

However, the program management team noted that many of these shortcomings could be overcome by setting meaningful code comment standards in follow-up contests. While the final product required further improvement, the program management team noted that the short innovation contest process provided a high quality product, a methodology that worked extremely well, intermediate products that provided great value, built in quality assurance, and a nimble, flexible and cost effective procurement process.

Cost Summary

Costs are broken down into (1) Challenge Posting Fees - TopCoder, (2) Labor Fees – CMS, Minnesota, COECI and NASA Tournament Lab, and (3) Prize Purse. The *upstream costs* here are the challenge posting fees and the labor fees, while the *downstream cost* includes the prize purse. The TopCoder fees are accounted for within the challenge posting fees. The total costs of the contest were estimated to be $1,520,600. A summary of the total cost breakdown is provided in Figure 8.

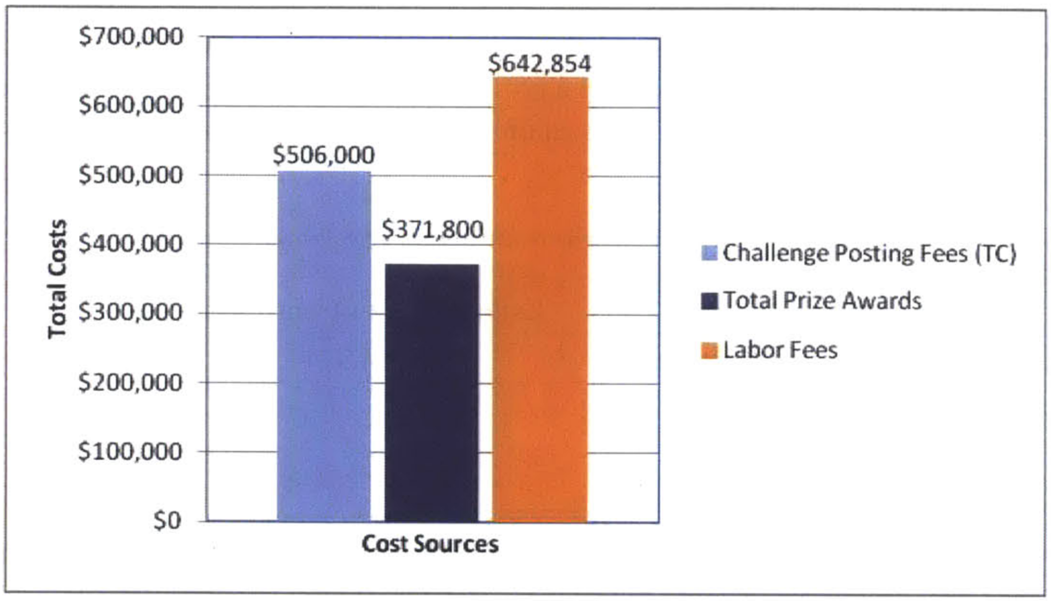

Figure 8: CMS Provider Screening Innovator Contest Cost Overview.

The upstream costs contributed to 76% (~ $1,148,854) of the contest's total costs (TopCoder's challenge posting fees at 33%, and labor fees at a combined total of 43%). The downstream cost contributed to 24% ($371,800) of the total contest costs.

Counterfactual

To analyze the cost efficiency of this contest, upstream and downstream costs of this contest were compared to the upstream and downstream costs estimated to occur if a provider screening module were to be created through one of CMS's traditional contractors.

Upstream Procurement Costs:

The acquisition cost of traditional procurement makes up the upstream cost which will be compared to the upstream cost of the contest. Because the total cost of this contest was above

$1M, it is outside the scope of the original upstream cost estimate. In this case, a CMS program manager provided a detailed cost estimate for the work required to acquire this technology through a traditional contractor. From his estimates, the upstream cost would include significant infrastructure development and project support, accounting for approximately 24% of the contract cost. The cost estimate for upfront work for traditional procurement was quoted at $1,453,089.

Downstream Procurement Costs:
The program manager of this contest provided a quote for the estimated contract cost if his team were to hire their prime contractor to develop a provider screening module. To procure the same technology acquired through a contest, it was estimated that a contract totaling $6,004,924 would be required.

Table 13: Estimated Cost of Traditional Procurement for the CMS Provider Screening Contest.

Contractor	Estimated Contract Cost
CMS Contractor	$6,004,924

Counterfactual Summary:
The estimated findings for upstream and downstream procurement costs are compared to those found for the CMS Provider Screening Innovator Contest in Table 14.

Table 14: Upstream and Downstream Cost Summary for the CMS Provider Screening Contest.

	Upstream	Downstream	Total
CMS Prime Contractor	$1,453,089	$6,004,924	~$7,458,013
Contest	$1,148,854	$371,800	$1,520,654

The total cost estimated to acquire a comparable solution through traditional procurement methods was found to be about $7,458,013. Contest total costs were found to be approximately one fifth of this. While the upstream contest costs were somewhat comparable to that of procurement, the cost savings were found in the downstream costs where contest costs were roughly 6% that of procurement. While the current solution is implementable for the Minnesota state program, further follow-up contests will be required to refine the solution such that it can be reused in other state programs. These follow-up contests are *not* expected to increase the total cost of the contest significantly since most of the work required was completed upfront.

CHAPTER 6

6 Program Management Highlights and Lessons Learned

The previous section presented examples where short innovation contests provided government agencies a cost effective alternative for technology procurement for certain circumstances. The results from these case studies as well as other successful contest initiatives lead us to ask, why aren't organizations launching contests all the time?

The reasons may lie with the differences between the organizational models of closed innovation strategies and open innovation strategies. The shift from traditionally closed innovative methods to open design methods are associated with organizational transformations as they involve integrated changes in the organization's boundaries, competencies, culture, structure and identity (Lakhani, et al., 2013). Integrating more open design strategies into an organization means creating a more complex set of innovation logics that federal managers must learn how to cope with internally.

Program managers are understandably cautious about implementing this new innovation tool. In addition to the hesitation experienced by changing business as usual, short innovation contests also provoke a "not invented here" mentality. Outsourcing a technical challenge to a crowd instead of solving it internally can have nontrivial cultural implications. There is also uncertainty in how much it would cost to run a contest, processes required to implement a contest, and the quality of solutions you would receive from the crowd (Boudreau, et al., 2013).

While extensive work is required to understand the full implications of infusing open design strategies into an organization, this chapter works to address certain key issues that arose in the four short innovation contests studied. To shed light on important management considerations necessary to implement this new innovation tool, the program managers from the four short innovation contest case studies were interviewed with questions that fall into three categories shown in Table 15 as: Pre-contest considerations, contest design and operation decisions, and post-contest learning.

Table 15: Program Management Interview Categories.

1	**Pre-Contest Considerations**
2	**Contest Design and Operation Considerations** 1. Risk 2. Scope 3. Time 4. Quality 5. Cost
3	**Post-Contest Learning**

The following sections summarize the conversations had with these program managers. The first section highlights key decisions that were made within the five management demands of risk, scope, time, quality and cost. The second section outlines the major challenges encountered throughout the implementation process. Lastly, the third section describes their major takeaways and lessons learned.

6.1 Management Considerations in the Five Competing Demand Framework

Over the past decade, a number of different standards have been proposed to increase the professionalism of project management. However, the strategies and processes outlined in the Project Management Institute's Project Management Body of Knowledge (PMBOK®), have gained widespread recognition and have "become the de facto global standard for project management" (Thomas, 2008). PMBOK® defines project management as "the application of knowledge, skills, tools, and techniques to project activities to meet project requirements." In describing the primary work of a project manager, PMBOK® identifies five competing demands within a project that must be considered: risk, scope, time, quality and cost.

Table 16: Five Competing Demands for Program Managers.

1	Risk
2	Scope
3	Time
4	Quality
5	Cost

This section outlines the considerations and decisions that program managers made within this framework. Each section begins with the appropriate contest management question related to that specific demand. Next, an overview of this demand in the context of short innovation contests is presented. Lastly, insights from the interviews with program managers are used to outline the factors that affect how the program managers in the analyzed case studies thought about this question.

(1) Risk

Question
How does infusing a contest into my project affect the risk profile of my program?

Overview
The concept of risk can be thought of as the uncertainty in other competing demands: uncertainty that a contest will be over budget, over schedule, or result in low quality solutions.

Interview Highlights
Program managers mostly considered risk when selecting the specific technology need the contest would be designed to provide. Because this was the managers first time running a contest, there was already inherent uncertainty employing this new business model. To account

for this, most program managers selected a technology need within their organization that would provide benefit if obtained, but would not negatively affect other programs if no sufficient solutions were found through the contest. In fact, one program manager described the contest technology need selected as one that was not really required at all. He described the technology need as one that already had a sufficient solution, but would be too expensive to optimize through traditional means. He chose to engage in a contest because it was an opportunity to try a new business model that could potentially be a cheaper path to optimization.

However, it was still important that risk was managed carefully. While it may be true that an unsolved technology need in most of these case studies would not negatively affect other programs in a significant way, there remained the risk of wasted time and resources if the contests were unsuccessful. Also, it is likely true that once a program manager became more confident in using short innovation contests as a technology procurement tool, higher value technology needs may be selected.

Program managers stated that risk could be managed by clearly defining the tasks that were required to set up a contest. To do this, a contest design team must (a) identify currently accessible data or models that could easily be leveraged for a contest and (b) identify additional data/models that would need to be obtained in order to make the contest work. The contest design team should have a clear plan going forward before getting into the contest specifics. Insight drawn from conversations with the contest expert, TopCoder, was said to be especially helpful in understanding what information/data would be required to run the contest.

(2) Scope

Question
What is the appropriate scope of a contest problem definition?

Overview
The scope of the problem is determined by the contest's problem definition provided to TopCoder participants. The scope of a contest can be defined by the number of and inherent difficulty of the solution requirements provided to TopCoder solvers at the onset of a contest.

Interview Highlights
Section 4.4 described how contests can be designed for problems with a wide range in scope that include Grand Innovation Prize contests which run over the course of several years as well as short innovation contests which are designed to be solved within a few weeks. The scope of a contest should appropriately match the amount of time participants will need to contribute meaningful solutions.

Determining the scope of a contest problem is closely entwined with the challenge of modularizing a problem. TopCoder specializes in contests that are run over the course of a few short weeks. Therefore, the program managers were challenged to break down their problem such that it could be solved within that timeframe. More complex problems could be broken down into several smaller problems. For example, the CMS Provider Screening Innovator Contest was so complex that it was broken down into a long series of smaller contests. Proper decomposition and modularization of problems is a highly complex issue and is not one covered in detail in this thesis.

When deciding the scope of the problem, program managers noted that "to get the right answer, you need to ask the right question." Asking the right question however can be difficult for more complex problems. For example, in the case of the ISS Longeron Shadowing Contest, NASA designed an initial contest to develop a less detailed faster ISS model which would be used in follow-up contests. The program manager was challenged with setting scope requirements for this first contest such that the ISS model would be simple enough to run quickly and used easily by participants without industry expertise but also include the necessary variables and constraints in order to be accurate. In the words of Albert Einstein, it needed to be as simple as possible, but no simpler.

Other factors must also be taken into consideration when deciding the scope of a contest. It was stated that managers should select an important problem faced by the organization, which would be challenging and interesting to TopCoder participants, but also solvable within a short time frame. The contest scope must also be appropriately matched by the prize purse and contest length. TopCoder's contest expertise provided crucial insight in defining the appropriate scope of each contest and pairing this with an appropriate prize purse and contest length.

(3) Time

Question
How long will it take my team to design a contest?

Overview
This demand involves the process of identifying and decomposing tasks required to design and implement a contest and organizing these tasks onto a schedule. The tasks for short innovation contests will typically fall under the five main phases: problem definition, contest design, contest operations, judging, and solution implementation.

Table 17: Main Contest Phases.

1	Problem Definition
2	Contest Design
3	Contest Operations
4	Judging
5	Solution Implementation

In some cases, an additional phase of Advertising may be desired before Contest Operations. It is also important to consider the time required to ensure that the necessary internal legal, budgetary, and procurement policies are in place.

Interview Highlights
If an organization is new to implementing short innovation contests, the timeline for contest development will include inherent uncertainty. Because of this, it was imperative for each program manager to consult TopCoder to help identify and decompose tasks required for each of the five main contest phases.

It was noted that nearly 75% of the work occurs before the contest begins and that these tasks were the most important to ensure the contest's success. These tasks will fall under the first two phases of (1) problem definition and (2) contest design. The tasks required in these two phases will be dependent on the complexity of the contest as well as the data or models that need to be acquired.

Unnecessary schedule slips would occur when the program management's schedule did not properly align with TopCoder's schedule. Therefore, it was important for the program managers to maintain close communication with TopCoder to properly manage the schedule throughout all five phases. Also, program managers limited the time required for solution implementation by identifying the preferred format of the solution and setting it as a requirement for all submissions.

(4) Quality

Question
How do I control the quality of submissions?

Overview
The quality of submissions is determined by judging criteria decided upon by the challenge sponsor. Typically for software contests, solutions will be given a numeric grade and the submissions will be ranked upon completion of the contest.

Interview Highlights
The desired quality of a submission must directly inform the judging criteria which is presented to contributors at the start of a contest. Implementing these criteria will likely be more straightforward in software contests than it will be in contests that require product design. For software-based solutions, it may be possible to automate the process by which submissions are graded.

Program managers referred to TopCoder for assistance in deciding the scoring metrics. The scoring metrics for the USPTO Patent Labelling Contest, for example, was based on an image detection scoring template that TopCoder had used for other similar contests. TopCoder's scoring templates could be used as a reference and catered to specific contests.

One program manager's advice in selecting scoring metrics was to try to ensure that no two submissions would receive the same grade and that it would be highly unlikely that any solution would receive a perfect score. Also, because TopCoder participants are likely only concerned with winning the contest, the program managers should take care in preventing opportunities for participants to game the system in a way that would result in a high score, but not provide a high-quality solution.

Another way to control the quality of submissions was by employing TopCoder "Bug Hunt" competitions (TopCoder, 2012). Bug Hunt competitions were run as follow-up contests to ensure that the top submissions met all of the necessary requirements. Prizes were issued for each "bug" a participant found. By running these competitions, program managers were more confident in the quality of the solutions they received.

Lastly, the nature of a short innovation contest and its highly iterative, short cycle processes means that many different products are being defined and produced simultaneously. This is especially true when contests are run as a series. One problem, which was identified in the CMS Provider Screening Innovator Contest, is that the final product may be highly fragmented and poorly documented. To avoid this, strict commenting requirements should be employed especially in contests that are run as a series. One program manager noted that a concerted effort must be made to properly manage the integration of these products into working components that meet functional requirements in order to manage the quality of the final product.

(5) Cost

Question
How much will it cost to acquire technology through a contest?

Overview
The sources of cost in a contest are found in the challenge platform fees, labor fees required to design the contest, and the overall prize purse.

Interview Highlights
The cost of running a contest will depend on how complex and difficult the challenge is and how well prepared the organization is to run that specific contest. For more difficult challenges, participants will need greater incentive to participate which will correspond to a larger prize purse. Similarly, more complex challenges will take longer to design and implement which will lead to more platform fees paid to the contest platform (TopCoder in these cases) and potentially more program management labor fees. Also, most challenges require a set of data or a model to be given to participants. If an organization already owns this data or model in the proper format, it will reduce the total cost of designing a contest.

One way to manage costs is for the program management team to maintain the same schedule with TopCoder. This helps to avoid periods of waiting on either side for answers or work and can save time in the long run. By doing this, the monthly platform fee paid to TopCoder and additional labor fees can be minimized.

6.2 Major Challenges Encountered

Interviews with the program managers revealed common challenges encountered when employing this new type of business model. These challenges were found in the areas of: (1) modularizing an organization's problem, (2) extracting an industry-specific problem into a contest that could be solved by a general audience, (3) determining roles and responsibilities, and (4) implementing and trusting the output of a contest.

(1) Modularizing the Problem

Overview

In order to launch a contest, a program manager must compartmentalize a problem in such a way that it can be used in a contest. The contest design team will need to narrow down a problem to the core requirements necessary to produce a useful solution.

Major Challenge

Program managers noted that when designing the contest, the fewer constraints you have, the easier it will be to get the contest up and going. However, the contest design team must also ensure that all necessary requirements and constraints are included such that the solutions you receive will be useful. This was the case when designing a simple ISS surface model that could be quick and simplistic, but also produce useful solutions.

Overcoming the Challenge

One strategy that will allow a program manager to solve a complex problem through contests is by breaking down the problem into multiple simpler challenges. These smaller, simpler challenges can be run on TopCoder as a series of contests. The difficult task of compartmentalizing a problem in general was found to be made easier by consulting TopCoder for advice.

(2) Extracting the Problem to a General Audience

Overview

One of the benefits of using a contest to solve problems is the ability to tap into a large diverse knowledge base around the world that is traditionally outside an organization's reach. In order to tap into this vast knowledge pool, however, a contest design team must design a contest in such a way that it can be understood and solved by a general technical audience.

Major Challenge
Many industry specific problems can be narrowed down to core problems defined in the language of mathematics or translated into common software languages. But the act of identifying and extracting the "core problem" and translating this problem into mathematics and/or software languages can be very difficult.

Overcoming the Challenge
The fact that a contest is designed to solve a problem at NASA or within the healthcare system can make the contest intrinsically interesting and help attract solvers to your problem. However, when designing the problem the contest design team must define it in such a way that solving does not require specific industry knowledge. To leverage the large diverse pool of TopCoder solvers, program managers had to find a way *not* to make the challenge centered on aerospace or healthcare. The goal of this process is to get to the root of the problem and extract the challenge such that TopCoder's general technical knowledge base could contribute solutions. TopCoder's insight proved crucial in this process.

(3) Determining Roles and Responsibilities

Overview
Designing a contest on the TopCoder platform requires work from both the challenge host side and the TopCoder side. Tasks and responsibilities must be clearly defined and allocated between TopCoder and the challenge host so that both parties can layout and align contest development schedules.

Major Challenge
As this was the first time using short innovation contests for the program managers, there was great uncertainty surrounding the distribution of responsibilities between themselves and TopCoder. One program manager stated that his team initially believed that there was little work required in hosting a contest - you would simply throw a general problem out to the crowd and the crowd would return with answers. They soon found that there was much more work and strategy involved than anticipated. It was stated by other program managers that they would have simply preferred for TopCoder to tell them exactly what to do. However, because TopCoder specialists cannot have domain expertise for every challenge they host on their site, the contest sponsor is responsible for determining much of the work that is required to design their specific contest.

Overcoming the Challenge
Program managers are relying on TopCoder to provide crucial insight as to what is required from

them in designing a contest. Program managers must actively engage TopCoder and clearly state any questions that arise in the contest design process. It is especially important for program managers to learn about the capabilities available to them through the TopCoder platform. Understanding the types of contests that TopCoder can run for them and other tools available will help inform the tasks necessary to implement a contest.

(4) Implementing and Trusting the Solution

Overview
Once a solution is identified and a TopCoder winner is selected, the contest host will need to take that solution and implement it into their organization.

Major Challenge
The major challenges encountered by program managers regarding implementation could either be technical or psychological in nature.

First, complications can arise during the implementation phase if the solution is not in a format suitable to the contest host (e.g. programming language, use of specific variables, lack of necessary restraints, running a specific program or model, etc.). Typically the challenge host will set a required format at the onset of a challenge to avoid this complication. However, there are times when it is preferable to leave the decision of format up to the TopCoder participant so as not to prevent participants without specific programs or knowledge of specific programming languages from submitting solutions. There have also been instances where the software solution received was not described sufficiently by the winning participant. This makes it difficult for contest sponsor to properly understand and implement this solution.

Second, other problems can arise if the solution is not trusted by those who are using the solution. There is a risk of this occurring because the process of procuring technology through a contest is going to be different than through traditional methods. If an individual does not trust the process, they may not trust the outcome.

Say, for example, a faster more efficient model was developed by TopCoder solvers through a contest with the goal of replacing a slower more expensive model. Because the engineers within the contest host organization were not involved in setting the constraints and outlining inherent assumptions about the model that was created, they may not trust the outputs the contest model provides. This may lead to limited use of the new model which would limit the benefit of the contest.

Overcoming the Challenge
One way to overcome the formatting challenge is to mandate that solutions be submitted in a specific format. Along the same lines, modularizing the problem such that a solution can easily

interface with the necessary program or model is also important. To overcome the challenge of understanding the solution, specific commenting requirements for software submissions should be mandated.

Ways of alleviating the psychological challenge of trusting the process include identifying and involving all stakeholders in the contest design process, making sure to leverage "Bug Hunts" for TopCoder submissions, and keeping clear lines of communication with TopCoder. Program managers must identify the individuals within their organization who would actually be using the output of the contest. These individuals should be involved to some extent in the contest design process. Also, "Bug Hunt" contests can help to ensure that contest submissions meet the requirements that were agreed upon by the stakeholders at the onset of the contest. Lastly, program managers interviewed noted that the transparency of operations provided by TopCoder helped the contest sponsor trust the process and feel confident in the quality of solution.

6.3 Lessons Learned from Program Managers

Interviews with the program managers revealed common lessons learned from implementing a contest in their organization for the first time. These lessons have been organized under the topics of (1) how contests are similar to traditional procurement, (2) how they are different, (3) advice on selecting and defining contest challenges, (4) tips on how to implement a contest successfully, and finally (5) the main benefits of using a contest as a procurement tool.

(1) How contests are similar to the traditional procurement process

Preparing for a contest required much of the same work as preparing for traditional procurement through an RFP. Many program managers learned that contests are more structured and require more planning and organization than they had initially believed. Similar to an RFP, the contest design team must be specific about what they are asking for in order to receive submissions that are relevant and useful.

(2) How contests are different than the traditional procurement process

Procuring technology through short innovation contests provided program managers more flexibility in terms of changing requirements than through traditional procurement. While specific solution requirements and submission formats must be provided at the beginning of a contest, a contest sponsor has the option of tweaking these requirements and quickly running a follow-up contest after solutions have been received. These follow-up contests can be employed to steer solutions in a different direction or simply improve on the best solutions that were found in a previous contest. Because of this option, program managers that were interviewed described contests as "more nimble and flexible" than traditional procurement methods.

(3) Selecting and defining a contest problem

Program managers stated that a contest would be much easier to implement in situations where the organization already had easily accessible test data that could be turned over to TopCoder participants. If important test data is unavailable or difficult to acquire, it could lead to significant upfront preparation for a contest which will increase the time and budget necessary to implement a contest.

And while it is difficult, a contest problem must be one that can be decomposed into a single problem statement for the TopCoder community that will lead to an output that is implementable and useful to the organization. The problem must be made as simple as possible while retaining its essential challenges. The contest should be non-trivial yet solvable, meaning that it could reasonably be solved by an individual with the appropriate expertise within the timeframe of the contest.

The challenge of identifying which problems are appropriate to procure through short innovation contests is one that is extremely difficult and outside the scope of this research. However, the program managers in these cases felt more comfortable employing contests for problems that would not be implemented in life-critical systems. Other procurement mechanisms which mandate adherence to many detailed safety requirements are likely more appropriate strategies for obtaining these technologies.

(4) Benefits of Contests

The program managers interviewed highlighted a number of benefits and positive outcomes from using short innovation contests as a method for technology procurement. All managers noted that contests were an effective way to engage a large number of diverse participants to which they do not normally have access. For NASA sponsored contests specifically, contests can be used as a way to engage the public and incentivize them to participate in NASA programs. This is especially useful today as large government cutbacks drastically hurt traditional NASA public outreach programs (NASA Education, 2013).

Some program managers noted that a positive outcome of identifying and deciding on judging metrics for the contest forced them to think of quantitative ways to measure performance of similar projects internally.

Another key benefit noted by managers is that contests are nimble and flexible. The contest sponsor could gain knowledge from the output of an initial contest and use that understanding to re-design a follow-up contest within a couple of weeks. This fast capability is not available through traditional federal procurement strategies.

Lastly, the program managers found that it was intrinsically interesting to participate in a new tool for technology procurement and innovation. For many of the cases, implementing a contest for the first time was treated as an experiment or a side-project in order to learn about this new tool and work through the process of implementing it within their own group and organization. Program managers were pleased with the process and expressed interests in using short innovation contests in the future. Along the same lines, the use of short innovation contests was an effective signal that the organization was innovative and investing in new open strategies.

CHAPTER 7

7 Policy Framework

Over the past few years, there has been a movement from isolated experiments to a broader contest policy initiative intended to better leverage the benefits of prize-based contests in the government sector. Starting after the success of the first awarded X-PRIZE competition in 2004, select government agencies were provided prize authority and started employing Grand Innovation Prize (GIP) contests in their own programs. In 2004, the Defense Advanced Research Project Agency employed grand challenges in order to advance the state-of-the-art of robotic cars. In 2005, NASA established the Centennial Challenges Program which invited students, inventors, and entrepreneurial firms to compete in various space-related contests. In 2008, the Department of Energy sponsored the L-Prize, designed to spur innovation in new highly efficient, solid-state lighting products.

The early successes in these government sponsored GIP contests helped encourage contest related policy initiatives under the Obama Administration. The President and the Office of Management and Budget (OMB) have educated federal agencies on the use and common benefits of prize-based contests and encouraged agencies to employ them within their own organization. Also, new legislation providing "prize authority" to all federal agencies was passed under the America Creating Opportunities to Meaningfully Promote Excellences in Technology, Education, and Science Reauthorization Act (America COMPETES Act).

This chapter analyzes these initiatives and how they relate to short innovation contests run on challenge platforms such as TopCoder. The first section of this chapter outlines the progression of prize-based contest policy initiatives. The second section highlights the contracting authority selected by the NASA Tournament Lab and how this contract mechanism compares to the COMPETES Act authority. The last section outlines challenges and considerations relevant to expanding the use of short innovation contests in the federal context.

7.1 Prize-Based Contest Policy Initiatives

The progression of policy initiatives relative to implementing prize-based contests in government agencies is outlined below.

Timeline

January 2009
At the start of his administration, President Obama signed the Memorandum on Transparency

and Open Government which committed the Administration to creating a more transparent, participatory, and collaborative government. In this memo, the President instructed OMB to issue an Open Government Directive (White House, 2009).

September 2009
Nine months later, the President released the Strategy for American Innovation which called on agencies to increase their ability to promote and harness innovation by using policy tools such as prizes and contests, among other strategies (White House, 2011).

December 2009
In response to the President's instruction in January 2009, OMB issued the Open Government Directive (The Directive). The Directive required executive departments and agencies to take specific actions to further the principles established by the President's memorandum. One of these specific tasks was for each agency to develop their own Open Government Plan which would outline open initiatives being taken within their agency. The Directive also tasked the OMB Deputy Director for Management with issuing guidance for the increased use of prizes and contests to improve open government (Orszag, 2009).

March 2010
To fulfill this requirement, the Deputy Director of Management at OMB released the Guidance on the Use of Challenges and Prizes to Promote Open Government memorandum. This memo outlined the various authorities an agency could exercise in order to implement prize-based contests in their own programs (Zients, 2010). These authorities included the use of grants, cooperative agreements, other transactions authority, public-private partnerships, and through FAR-based contracts.

January 2011
In an attempt to expand prize authority provided to government agencies, Section 105 of the America COMPETES Reauthorization Act presented specific prize authority that agencies could exercise to employ prize-based contests (One Hundred Eleventh Congress, 2011). This new section on prize authority would not affect any existing prize authority enabled by other laws explained in the March 2010 OMB memo. Under the COMPETES Act authority, agencies could conduct contests similar to the GIP contests previously conducted by certain agencies, with up to $50 million in prizes and participation limited to U.S citizens.

7.2 Prize Authority for Short Innovation Contests

An important question to ask is whether the prize authority offered under the COMPETES Act is appropriate for short innovation contests. It is interesting to note that this contracting authority was not employed for the case studies in this thesis. This is because the NASA Tournament Lab came into existence before the COMPETES Act was envisioned. Therefore, an alternative contract mechanism (the FAR contract which was outlined within the March 2010 OMB memo) was selected to procure technology for the contest cases studied in this thesis. However, individuals at the NASA Tournament Lab have noted that limitations within the COMPETES Act authority make this authority not ideal for short innovation contests even if it were available.

This section first briefly describes how the FAR contract mechanism was employed for contest-use by the NASA Tournament Lab. Second, the limitations of COMPETES Act authority for use in short innovation contests is described. Finally, the importance of the distinction between short innovation contests and GIP contests as it relates to policy is outlined.

FAR Contract for Short Innovation Contests

When the NASA Tournament Lab set out to use contests as a strategy for technology procurement, it was not inherently obvious which contract mechanism was appropriate. The prize authority used for GIP contests like the NASA Centennial Challenges Program was not favored because, in general, under this authority technology rights are not easily transferred to the government agency. This was viewed as important because the NASA Tournament Lab wanted to use contests specifically for technology procurement.

Ultimately an Indefinite Delivery Indefinite Quantity (IDIQ) contract, a specific contract under FAR section 16.501(a), was selected as the contract of choice. The U.S. General Services Administration states that IDIQ contracts are selected when an agency cannot determine, above a specified minimum, the precise quantities of supplies or services that the agency will require during a specified contract period (General Services Administration, 2012). This was appropriate for short innovation contests because at the beginning of the contest design phase, it is not immediately clear how many contests will be required in order to create a sufficient solution.

Under the FAR-based IDIQ contract, the challenge platform TopCoder was viewed as a contractor. TopCoder simply employed prize-based contests as a strategy for procuring goods and services to the government. IDIQ was appropriate because it allowed for flexibility in the number of contests that needed to be run and software solutions that would ultimately be provided through TopCoder.

An interesting point is that in Chapter 2, FAR-based contracts were described as a high barrier for individuals and newcomers to partner with NASA. However, this problem was circumvented due to the emergence of challenge platforms like TopCoder which organize individual "solvers" specifically for prize-based contests. These challenge platforms are large enough to procure resources necessary to cope with FAR requirements, but also allow individuals to engage in government programs through the strategy of prize-based contests. This type of organized crowdsourcing had not existed a little over a decade ago. TopCoder, for example, organizes a community of over 470,000 "solvers" from around the world who regularly compete in both privately-funded and federally-funded contests.

Other challenge platforms have since emerged that organize solvers with different expertise and host contests related to different specialties. They source and retain "solvers", enable prize payments, and protect, clear, and transfer intellectual property worldwide (Boudreau, et al., 2013). Some of the more popular challenge platforms are described in Table 18.

Table 18: Challenge Platforms that Focus on Short Innovation Contests.

Challenge Platform	Specialty	Description
TopCoder	Software and Digital	A community of over 470,000 programmers worldwide who compete to provide innovative software and digital solutions.
Innocentive	Broad Range	A community of over 285,000 solvers with various expertise worldwide who compete to solve a broad range challenges in the domains of engineering, computer science, mathematics, chemistry, life sciences, physical sciences, and business (Innocentive, 2013).
Kaggle	Big Data	A community of over 88,000 registered data scientists worldwide who compete to solve complex data science problems (Kaggle, 2013) .
Tongal	Video	Started in 2008, Tongal hosts creative short-film and video contests (Tongal, 2013).

COMPETES Act Authority for Short Innovation Contests

Individuals within the NASA Tournament Lab and at NASA have suggested that even if the COMPETES Act authority were available to them, it would not have been selected as the contract mechanism to procure technology through short innovation contests. There were two main reasons why the COMPETES Act authority was deemed inappropriate for use in short innovation contests on a contest platform. First, it restricts contest participation to US Citizens, thereby drastically limiting the pool of solvers. Second, in general under the COMPETES Act prize authority, the intellectual property does not transfer from the "solver" to the contest sponsor. As a result of this, the liability also does not transfer from the "solver" to the contest sponsor, which places more risk on contest participants.

Limited Pool of Solvers

The COMPETES Act authority limits participation in federally funded prize-based contests to U.S. citizens. The purpose of such a restriction is to contain tax-payer-funded prizes, which could potentially sum to the COMPETES Act prize limit of $50 million, to a domestic audience. While this ensures that only U.S. citizens will benefit from federally funded prizes, it stifles the ability for contest-sponsors to leverage the wisdom of a diverse pool of participants. The contest cases studied in this thesis were hosted on the TopCoder platform which primarily consists of international solvers. As shown in Figure 9, over 70% of TopCoder solvers are *not* U.S. citizens. Limiting participation to U.S. citizens for short innovation contests run on the TopCoder platform cuts the pool of potential solvers to less than one third.

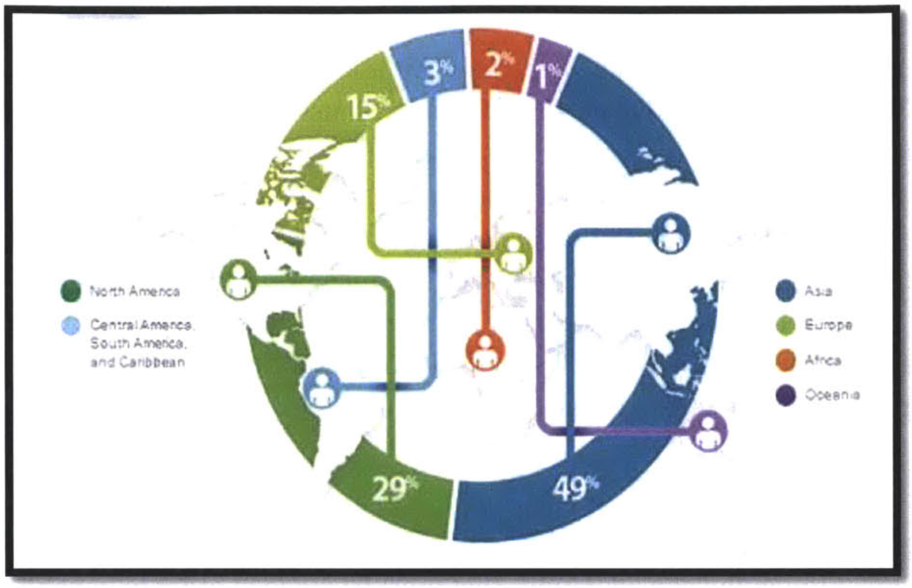

Figure 9: Demographic of TopCoder Registered Solvers. (2013)

This restriction is likely more appropriate for GIP contests, which was defined in section 4.4 as contests that typically offer prizes over $10 million, take place over the course of multiple years and require significant investments from participants. In GIP contests, intellectual property is primarily awarded to the "solver" and there are many instances where participants in GIP contests go on to launch companies with the technology developed through the contest. The X-PRIZE foundation has cited that one beneficial outcome of GIP contests is that they incentivize the creation of new industries and markets. In these cases, where most of the benefit is derived on the "solver" side, it makes sense to limit contest participation in federally funded prize-based contests to a domestic audience.

However, for federally funded short innovation contests, the primary goal is to obtain the most innovative technology for use in government programs. The solvers are awarded much smaller prizes than in GIP contests and the contest-sponsor owns the right to the awarded technologies. Therefore, in short innovation contests, where most of the benefit is derived on the government side, it makes sense to allow capable solvers from all over the world to submit solutions.

Intellectual Property Rights and Participant Liability

Under the COMPETES Act authority, contest participants are generally awarded the intellectual property for their contest submission. The COMPETES Act states that a government agency that sponsors a prize-based contest must "Take no interest in the intellectual property submitted to a prize competition without the written consent of the submitting participant." Although not impossible, this stipulation makes it difficult for a government agency to procure the technology solution resulting from a contest.

Tied to these intellectual property rights is the liability associated with that specific technology. The COMPETES Act states that all contest participants "must obtain liability insurance or demonstrate financial responsibility, in amounts determined by the head of an agency, for claims by third parties and the Federal government" (Bershteyn, 2012). The amount of liability insurance required depends on the risk that the participant's technology poses for death, bodily injury, or property damage. This stipulation places a burden of risk on the solvers, creates a high cost for contest participation and prevents those with few resources from contributing contest solutions. Because of this, the COMPETES Act is inappropriate for short innovation contests where a low barrier to participation is desired.

7.3 Expanding Use of Short Innovation Contests

This section works through the considerations that must be made in order to expand the use of short innovation contests in the government context. First the inherent challenges of employing this new innovation tool for federal procurement are outlined. Next, certain questions that must be considered to determine immediate action are presented. Lastly, key considerations for expanding the use of short innovation contests over the long term are explained.

Inherent Challenges

In order to implement prize-based contests, organizations must learn an entirely new strategy for technology procurement. This involves a steep learning curve and many organizations may experience cultural pushback to this change. Because contests may be seen as "crowdsourcing" a problem outside of an organization, agency's may also find members hesitant to implement short innovation contests due to a "not invented here" mentality. This could be especially true for traditionally more innovative agencies like NASA.

In order to assist organizations with the steep learning curve, contracting officers within each agency should be trained on the contract mechanisms available for short-innovation prizes. The OMB memo from March 2010 outlined eight separate authorities that could be exercised by government agencies to employ prize-based contests. However, too many contract mechanisms to choose from can be redundant and confusing. Therefore, standardization of a contract specific to short innovation contests must be identified. While the FAR-based IDIQ contract worked well for procuring technology with TopCoder, it must be determined whether this is also appropriate for procuring technology with other challenge platforms.

Short Term Evaluations

Among the various challenges described above, there are certain questions that must be considered to determine immediate action.

1. Which federal technology needs are appropriate for short innovation contests?
2. Is there a need to pass new legislation, similar to the prize authority in the COMPETES Act, but specifically for short innovation contests?
    a. In such legislation, should international participation be permitted?
    b. In such legislation, should intellectual property rights be transferred to the government?

1) Which federal technology needs are appropriate for short innovation contests?
The first question presents a very complex challenge. Because the use of short innovation contests for technology procurement is relatively new, it is difficult to determine which technology needs are appropriate for this strategy versus other forms of technology procurement. However, program managers of the studied cases suggested that appropriate technology needs included ones that were well understood, easily defined and able to be outsourced with the necessary supporting information for a technical audience to solve within weeks. Further work should be done to classify technology needs and match them to appropriate procurement methods.

2) Is new legislation required?
Because the COMPETES Act authority was deemed inappropriate for short innovation contests, the second question is really asking whether new legislation is required or if the FAR-based IDIQ contract is sufficient for implementing short innovation contests. The FAR-based IDIQ contract worked well for the NASA Tournament Lab to implement short innovation contests on the TopCoder platform. However, more work needs to be done to understand if this contract works well in all agencies and for all challenge platforms. The benefit of using this FAR-based contract is that it allows government agencies to work with a type of contract their contracting officers are already familiar with instead of having to learn an entirely new authority and contract mechanism. There is also the benefit of avoiding the effort required to pass new legislation.

2.a) Should participants be limited?

2.b) Should I.P. transfer to the government?

The two sub-parts of the second question address the limitations found in the COMPETES Act prize authority for short innovation contests. First, when selecting an appropriate contract mechanism, it is important to determine if international solvers should be allowed to participate in these short innovation contests. Second, it must be decided if intellectual property rights should be transferred from the participant to the government.

For short innovation contests, where the primary purpose is to identify the most innovative technology for use in government programs, it is suggested that *no* limitation be imposed to participation based on citizenship and the I.P. should transfer to the government. Under these measures, government agencies are in the best position to identify the best innovation available and own the rights to that technology.

For GIP contests, where the primary purpose is to stimulate a new industry around a specific challenge, it is suggested that participation be limited to U.S. citizens and I.P. remain with the contest participant. Under these measures, government agencies may enable the creation of new industries, new jobs, and new technologies in the United States. The government may even become a customer to some of the emergent companies.

These policy recommendations are summarized in Table 19.

Table 19: Short Innovation Contest and Grand Innovation Prize Contest Differences

Contest Type	Primary Purpose of Contest	Proposed Policy Related to Participants	Propose Policy Related to Intellectual Property/Liability	Expected Outcome
Short Innovation Contest	Identifying and procuring the most innovative technology	No limitations based on citizenship	I.P./liability transfers to government agency	The government is in the best position to procure the best innovation and own the rights to that specific technology.
Grand Innovation Prize Contest	Stimulation of a new industry and market	Limited to U.S. citizens	I.P./liability awarded to participant	The government will enable U.S. based individuals and companies to benefit from market stimulation efforts. These companies may turn into government contractors.

Long Term Considerations

As short innovation contests are increasingly used in government agencies, two questions should be reevaluated.

1. Who is receiving the most benefit from a short innovation contest: the government sponsor, or the contest participants?
2. What is the primary purpose of a short innovation contest: to procure the most innovative technology or to ensure that only U.S. citizens benefit from contest use?

Who is receiving the most benefit from a short innovation contest?

Regarding the first question, prizes for short innovation contests are relatively low, most on the order of $10,000 or less per contest, compared to GIP contests that can award up to $50,000,000 in prizes. In the short term, the government is receiving the primary benefit from a short innovation contest by incentivizing a large number of individuals around the world to contribute technology solutions and only awarding the most innovative submissions with relatively small prizes.

In the long term, however, as more agencies begin to employ short innovation contests more frequently, a greater total amount of tax payer dollars will be awarded in prizes. If a significant portion of these prizes are awarded to non U.S. citizens, we must question whether the government is still receiving more benefit than the winners of the short innovation contest which may reside outside the U.S. This is especially important if government agencies are procuring similar technologies and winning submissions are coming from outside the U.S. Without proper coordination between agencies, these efforts may inadvertently incentivize the creation of new industries outside the U.S. with tax payer dollars.

What is the primary purpose of a short innovation contest?

For the second question, government agencies must decide if their primary goal is to procure the most innovative technology for their agency. This will influence whether agencies place limitations on those who can participate in contests. One could argue that American taxpayer dollars should not be awarded to non-citizens in any circumstances. However, if the primary goal is for the government agency to procure the most innovative technology to implement in U.S. government programs, allowing submissions from around the world will give the government the best chance in achieving this goal.

CHAPTER 8

8 Conclusion

Today, we are experiencing a world in which increased access to knowledge and decreased communication costs have transformed traditional strategies for innovation. Previously, organizations could effectively innovate internally through completely closed design strategies. However, today with growing knowledge bases outside an organization's boundaries, it is imperative to identify strategies that enable fruitful partnerships with these innovative communities.

One specific open design strategy, short innovation contests, can enable government agencies to tap into large, diverse knowledge communities that are typically outside their reach. Short innovation contests can also help agencies overcome the challenge of imperfect competition in technology procurement under certain circumstances. While this innovation strategy can offer considerable advantages over traditional methods, program managers are understandably hesitant to engage this new procurement model. It seems unnatural to outsource a problem to a crowd of strangers and there is inherent uncertainty associated with this new tool.

This thesis provided an empirical analysis of four short innovation contests to shed light on the following research questions:

1. How do short innovation contests compare to traditional procurement methods from a cost perspective?
2. What are the key considerations made by program managers when using short innovation contests to procure technology?

To provide a context for this research, the problem of imperfect competition in the market of federal contracts, specifically at NASA, was described. Then, open design strategies were presented as a way to alleviate this problem and the literature around open design strategies was outlined. It was argued that short innovation contests were the most appropriate open design strategy for NASA to engage crowds for technology procurement for certain circumstances.

To understand the cost structure of short innovation contests, a cost efficiency analysis was presented for each of the four contest case studies. To understand the program management challenges and considerations, the highlights of the conversations with federal managers employing this tool for the first time were presented. Finally, the policy framework relevant to procuring technology through short innovation contests and implications of expanding their use in government was outlined.

This final chapter first provides a summary of the cost analysis of the four case studies analyzed. The next section presents the highlights from the program management analysis. The following section reviews a summary of the policy considerations for short innovation contests. Next, suggested further work on this topic is presented. Finally, the last section provides closing remarks for this thesis.

8.1 Summary of Case Study Cost Assessment

This thesis analyzed the cost associated with four short innovation contest run on the TopCoder platform. The costs were broken down into upstream costs (challenge posting fees and labor fees) and downstream costs (prize purse). These costs were then compared to the upstream and downstream costs for traditional procurement. This section provides a summary of the contest costs and their comparison with traditional procurement.

Contest Costs

The summary of the allocation of costs between challenge posting fees, labor fees, and the prize purse in the four case studies in this thesis is presented in Figure 10. The first three cases showed a similar distribution of costs between challenge posting fees (between 56% and 60%), labor fees (between 13% and 18%), and the prize purse (between 26% and 29%). The last case, the CMS Provider Screening Innovator Contest showed a higher portion of fees attributed to labor (43%) and less attributed to challenge posting fees (33%). This is likely because the CMS contest was designed to procure the most complex technology out of the four cases. The CMS contest was run as a series of over 140 contests over the span of eleven months, while the first three contests were run in one month or less. Also, for this case, there were many stakeholders required at the federal and state level to properly design the contest. The aggregate of this work contributed to significantly higher labor fees than the other contests.

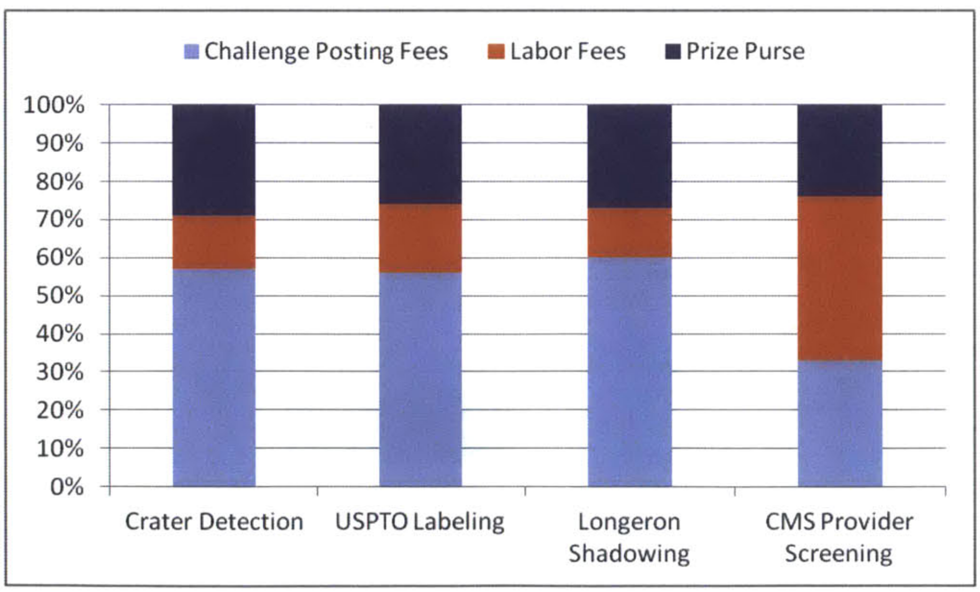

Figure 10: Summary of Contest's Cost Overviews.

Counterfactual Comparison

The summary of the comparison between contest costs and traditional procurement costs can be found in Figures 11 and 12 below. Due to the dramatic difference in total costs between the first three contests and the CMS contest, the CMS contest is shown on a separate figure with a differently scaled vertical axis.

In the figures below, each stacked bar on the left represents contest cost and each stacked bar on the right represents traditional procurement cost. These stacked bars show the comparison between the upstream (denoted by "U") and downstream (denoted by "D") contest cost and the upstream and downstream traditional procurement cost.

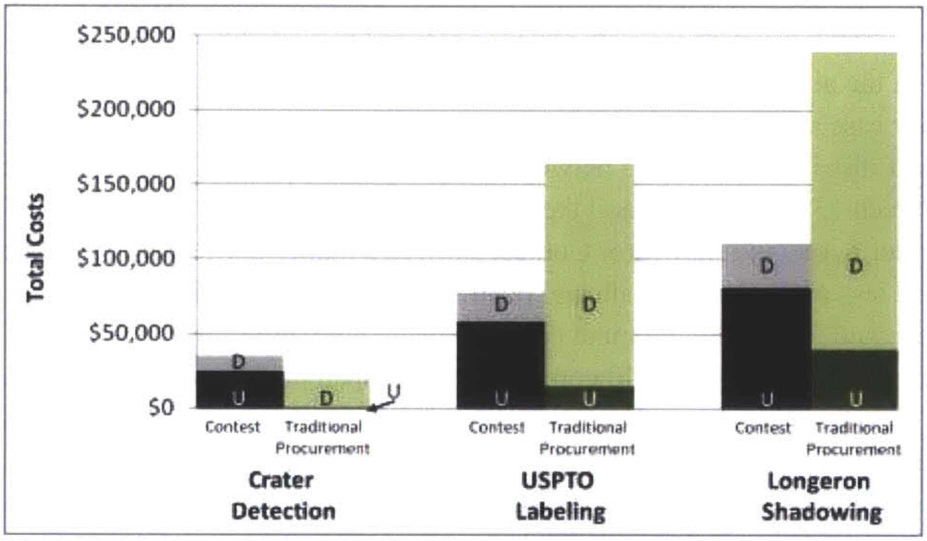

Figure 11: Counterfactual Cost Comparison Part A.

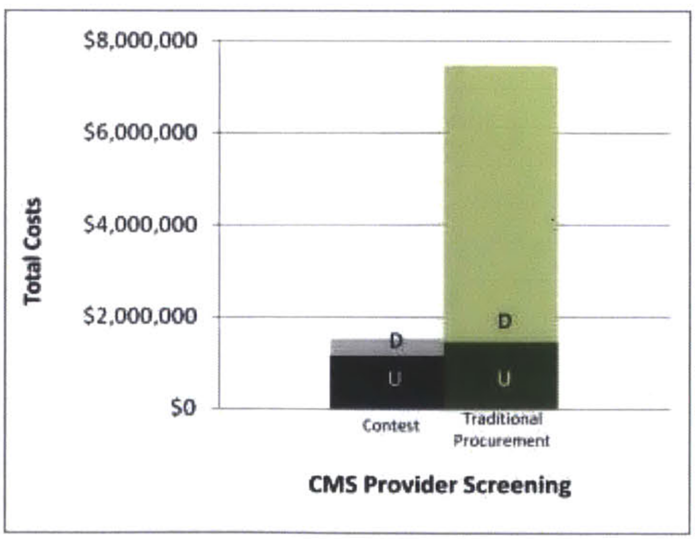

Figure 12: Counterfactual Cost Comparison Part B.

For three of the four contests, the total cost of the contest was much less than the estimated cost of procuring a similar technology through traditional procurement. The exception, the Crater

Detection Contest, showed that traditional procurement was expected to cost less than the contest. This could be due to the fact that this problem selected for procurement was one that was simple enough that it could be solved by a summer intern at low-cost, while the three other contests were more complex.

It should also be emphasized that these were cases where a program management team was running a short innovation contest for the first time. There is a learning curve associated with short innovation contest use and therefore less time may be required to design and run contests in the future. After becoming more familiar with contest-use, decreased contest upstream costs could be expected.

These counterfactual comparisons showed significant cost avoidance for three of the four contest case studies. While these results are promising, more work must be done to determine which technology needs can be procured more cost effectively through short innovation contests than through traditional procurement.

8.2 Summary of Program Management Considerations

The program managers were interviewed about their experience implementing short innovation contests for the first time. From these interviews, it was determined that there were four main challenges encountered. These challenges included:

1. Modularizing a problem such that is simple enough for be broadcast to a general audience, but also includes necessary constraints and requirements
2. Extracting the core challenge from an industry-specific problem to be solved by a general audience
3. Determining the distribution of roles and responsibilities between the program management team and TopCoder
4. Implementing the final product and trusting the quality of the solution.

Program managers also noted the similarities and differences between using a short innovation contest for technology procurement versus using a traditional procurement mechanism. They noted that contests were similar to traditional procurement in that you must "ask the right question to get the right answer." By this, they meant that just as their team would need to specify key requirements in an RFP, they must include key requirements in the judging criteria of a contest.

Program managers noted that contests were different in that they were much more nimble and flexible than traditional procurement. With contests, if the management team was not satisfied with the solutions from a contest, they could quickly redefine requirements and launch a new contest just weeks later. Similarly, if the management team wanted to improve on any solutions received, a follow-up contest could be run where participants were provided and prompted to improve upon previous submissions.

Lastly, program managers noted a few lessons learned on short innovation contest best practices. They noted the importance of involving all stakeholders in the design of the contest, especially those within the organization who will be expected to implement the solution. It was also important to ensure that necessary test data and/or models that will be required for the contest were easily accessible. Lastly, program managers noted the importance of ensuring that the requirements and judging metrics provided to TopCoder participants were matched to the goals and expectations for submissions. This is primarily because TopCoder participants will only be concerned with obtaining the highest score so that they can win the prize. Therefore, the metrics should be selected such that the best score will correspond to the highest value product.

8.3 Summary of Policy Considerations

Chapter 2 presented different reasons for imperfect competition in the market of federal contracts. These inefficiencies were divided between situational inefficiencies and bureaucratic inefficiencies. Congressional and Executive Branch actions to address these inefficiencies were outlined and the reasons why these actions proved ineffective were described.

Short innovation contests were proposed as a solution to address certain inefficiencies and improve the overall competitive market for certain contracts. Through open government initiatives led by the Obama Administration, existing authorities – including FAR-based contracts – that would allow government agencies to employ prize-based contests were outlined and described. In addition to this, a new prize authority under the America COMPETES Reauthorization Act was created in an effort to expand prize authority provided to government agencies.

The case studies in this thesis opted to use a FAR-based contract to procure technology through short innovation contests. Traditionally, the FAR has been criticized as being too complex and creating a high barrier to government partnership for those with limited resources. However, the emergence of private companies that organize individuals around the world specifically for prize-based contests circumvented this issue. These private companies, like TopCoder, are large enough to cope with a FAR-based contract and can be hired as a contractor to procure a certain technology. TopCoder simply uses the strategy of short innovation contests to procure the specified technology for the government agency.

The differences between the FAR-based contract and the new prize authority listed under the COMPETES Act were found to be in their policies related to participants and their policies related to intellectual property. FAR-based contracts with TopCoder did not restrict users based on their citizenship while the COMPETES Act authority did. FAR-based contracts with TopCoder transferred technology rights to the government agency while the intellectual property under the COMPETES Act authority generally stayed with the participant. Because the primary goal in short innovation contests is to identify and procure the most innovative technology, the FAR-based contract policies were argued to be more appropriate for this procurement strategy.

8.4 Recommendations for Further Research

Through this work, three key challenges were identified related to understanding and expanding the use of short innovation contests. These challenges involve identifying contest-appropriate technology needs, modularizing such problems in a contest-appropriate format, and organizational infrastructure required to support innovation contests.

First, more work must be done to understand which types of technology needs are appropriate for short innovation contests versus other technology procurement methods. Federal program managers have many tools to procure different types of technologies and they must be given the knowledge to determine which innovation problems should be solved internally versus externally.

Second, further work is required to understand how to properly decompose a complex technology need such that it can be procured through a short innovation contests. Complex problems must be modularized such that an output from the short innovation contest will provide value to the government agency. However, this problem must be simple enough to be solved within a few weeks on a challenge platform. More insight is required to aid federal program managers in decomposing and modularizing technology needs for contest use.

Third, more work is required to understand the organizational implications of government agencies employing short innovation contests. Contracting standards must be decided on for procuring technology through short innovation contests so that contracting officers can make informed decisions on contract selection. Lastly, additional work is necessary to understand how organizations can motivate employees to consider short innovation contests as an option for technology procurement.

8.5 Closing Remarks

This thesis presented a type of open design strategy, short innovation contests, as a technology procurement method that would lead to improved competition for certain government contracts. Program managers remain understandably cautious about this new open design strategy. This thesis endeavored to shed light on these uncertainties through an empirical analysis of short innovation contests piloted at different federal agencies. These examples, as well as other recent contest initiatives, have demonstrated the potential power of leveraging a crowd through prize-based incentives in a cost effective way for certain technologies. Further work is necessary to properly understand short innovation contests as a procurement strategy. However, organizations now have a unique opportunity to partner with the growing knowledge base outside their boundaries, which is increasingly important as access to information grows and costs of communication and innovation continue to fall.

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Appendix I

Table 20: Interviews with Key Individuals.

Title	Name	Topic of Interview(s)
Director, Human Health and Performance, NASA	Jeffrey R. Davis, MD	Provided insight about the use of contests in the government context and the policies relevant to contest authorities.
Director, Advanced Exploration Systems Division at NASA	Jason Crusan	Provided insight about the use of contests in the government context, the polices relevant to contest authorities, and the selection of the contract mechanism for the NASA Tournament Lab.
Senior Vice President, Government Platforms at TopCoder	Andy LaMora	Provided insight about the TopCoder platform itself and information about the four case study contests including the TopCoder fees associated with each.
Center of Excellence for Collaborative Innovation External Agreement Manager	Karl Becker	Provided insight for acquisition costs for NASA contracts and as well as the use of contests in the government context.
Chief IT Strategist for the U.S. Patent and Trade Office	-	Provided insight for the USPTO Patent Labeling Contest as well as cost information associated with the labor fees for this contest.
Manager of the ISS Vehicle Integrated Performance and Resources Team	William Spetch	Provided program management insight for the ISS Longeron Shadowing Contest, cost information associated with the labor fees for this contest, as well as estimated costs associated with a traditional procurement for this case study.
Senior Technical Director, Data & Systems Group, Center for Medicaid & CHIP Services, Centers for Medicare & Medicaid Services	John "Chip" Garner	Provided program management insight for the CMS Provider Screening Innovator Contest, detailed information associated with costs incurred for this contest, as well as detailed estimated costs associated with a traditional procurement for this case study.
Planning Director, HealthCare Operations, State of Minnesota	-	Provided program management insight for the CMS Provider Screening Innovator Contest and cost information associated with the Minnesota labor fees for this contest
Director of the Intelligent Robotics Group, NASA	Terry Fong, PhD	Provided program management insight for the Crater Detection Contest.
Senior Scientist, Intelligent Robotics Group, NASA	Ara Nefian, PhD	Provided program management insight for the Crater Detection Contest, cost information associated with the labor fees for this contest, as well as estimated costs associated with a traditional procurement for this case study