Prizes, Prize Culture, and NASA's Centennial Challenges

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Technology prizes and competitions are presented, including a history of the use of such prizes, how prizes compare with more common procurement instruments (e.g. contracts and grants), and the many lessons that have been learned through their use. Next, the concept of a "prize culture" is presented and common stereotypes and misconceptions about prizes are identified and addressed. Finally, an overview of the Centennial Challenges program is presented, including its origins and current status.

I. Prizes

A. Introduction to Prizes

Prize competitions have been used throughout history to accelerate the development of many different technologies. The desire for new or better technologies have often come from unmet needs in various sectors of society, including commerce, industry, military, public safety, public health, and adventure/tourism.

The history of successful prize competitions has shown the potential for break-through developments and the accomplishment of feats thought to be "impossible." In most cases, the detrimental effects are negligible for a competition when the prize is not won, because there was little cost and no resulting purse payment.

Although the U.S. government has a long history of awarding medals to individuals of merit (a.k.a. 'recognition prizes'), it has only recently begun experimenting with inducement prizes to spur technology developments in selected areas. Centennial Challenges is a program recently initiated at the National Aeronautics and Space Administration (NASA) to apply the prize philosophy to its aeronautics, space science, and exploration goals.

A review of past prize competitions helps to identify some best practices and common pitfalls to guide future competitions.

B. Prize History

Prizes dating back to the 18th century have stimulated technological advances and enhanced various sectors of society, including commerce, industry, the military, public safety, public health, and adventure/tourism. Prize competitions spurred the development of vital technologies during the birth of aviation. A renaissance of competitions and prizes have been offered by for-profit companies, non-profit organizations, and the government as well.

The following prize competitions conducted between the 1714 and 2004 were described in a previous paperSuperparanumonly:

1. 18th and 19th Centuries Prizes

- The British Longitude PrizeSuperparanumonly

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- The Alkali Prize
- The Food Preservation Prize

2. 20th Century Aeronautical Prizes

- The Deutsch Prize
- The Daily Mail English Channel Crossing Prize
- The Milan Committee Prize
- The Daily Mail Trans-Atlantic Prize
- The Hearst Prize
- The Orteig Prize
- The Kremer Prizes

3. 21st Century Prize Competitions

- The Cheap Access to Space Prize
- The ANSARI X PRIZE
- Defense Advanced Research Projects Agency (DARPA) Grand Challenge 1 (conducted in March 2004)
- The Feynman Grand Prize
- The Methuselah Mouse Prize

Additional prize competitions that have been or will be offered or conducted include the following:

- DARPA Grand Challenge 2 (conducted in October 2005) - A purse of $2 million for an autonomous ground vehicle that most quickly navigates a designated route over desert terrain within 10 hours. This time, however, four teams finished the entire course in less than ten hours and the winner was the Stanford University team with a total time of 6 hours 53 minutes.
- DARPA Grand Challenge 3 (to be conducted in November 2007) - A purse of $2.75 million split into three prizes for a 60-mile, urban course to be conducted in under six hours. The vehicles will be required to successfully obey traffic laws, merge with existing traffic, and negotiate intersections such as traffic circles.Superparanumonly

4. Impact of Prizes - One Example

Although the early European aviation prizes were generally hosted, conducted, and won by Europeans, they had an great impact on the development of the American aerospace industry from the beginning. This is demonstrated by events in the early 1900s:

> The progress of European aviation due to prizes and competitions became troubling to US observers. Dr. Albert F. Zahm, head of the revived Smithsonian aeronautical laboratory originally founded by Samuel Pierpoint Langley, was dispatched to Europe along with Dr. Jerome C. Hunsaker of MIT to study the situation there. Zahm's report, issued in 1914 emphasized the disparity between European progress and American inertia. The report led to the creation of the Advisory Committee for Aeronautics (later known as the National Advisory Committee for Aeronautics or NACA), the predecessor of NASA.Superparanumonly

C. Comparison with Other Procurement Instruments

Like contracts and grants, prize competitions are a procurement instrument (or method) that are best applied in specific situations. Direct purchase from the open market is best used to procure goods or services that already exist and are readily available. To procure something that does not yet exist, however, only prizes and contracts/grants can be used. To compare them directly, major features of prizes and contracts/grants are listed in Table 1 and described in detail below.

TABLE 1. Comparison of Procurement Instruments: Contracts and Grants vs. Prizes

Item	Contracts/Grants	Prizes
Selection Process	"Crystal Ball" - Prejudges which competitor has best chance of success	"Darwinism" - All competitors compete until end of contest
Results	One possible per contract	Many possible
Successful Delivery	Depends on ability to select best competitor.	Depends on ability to formulate achievable rules

Eligibility	Companies able to navigate contracting regulations	All US citizens (some exceptions), non-Federal employees
Cost to NASA	Rarely less, and often more than 100% of costs	A fraction (<20%) of total cost
Payment of Funds	Most funding paid out before delivery of hardware or service	Payment ONLY after successful demonstration of hardware or service

1. Selection Process

The selection of a winner for contracts and grants is very different from selection of a winner for prizes. For contracts and grants, representatives from the funding organization solicit proposals by issuing a set of requirements in the form of a statement of work. Responses to these requirements are then submitted by potential contractors and grantees to a selection committee. This selection committee then must evaluate all the proposals to the best of their ability, sometimes with limited technical competency, time and level of effort. Typically, a scoring methodology is followed in an attempt to quantify the selection process of determining a winner.

Due to the basic nature of contracting for new developments in technology, and despite the great effort that is made to follow a process that is objective and fair, it is not possible to guarantee that the outcome will select the best contract or grant. Selection officials must use their best judgement and some level of guessing as to which proposal will best perform the work successfully. Using the analogy of a fortune teller's crystal ball to tell the future, the selection committee must use their powers of prognostication, in addition to their technical competency and experience, to clear as much of the fog inside the crystal ball as possible, with the intent of determining who among the proposers can best fulfill the contract terms. Sometimes the selection is influenced by preconceived notions held by the evaluation committee members, thereby predetermining the form of the solution.

Under the prize methodology, there is no need to tell the future, let alone evaluate proposals. Any participating team must actually fulfill the requirements (goals, not specifications) of the original statement of work before they can claim the prize. Also, the form of all the participating entries is only influenced by the way the original rules are written. If written correctly, rules will not favor, predetermine, or assume the design of any competition entry.

2. Results

In the case of most contracts or grants, the result will be the predicted solution for the given statement of work. In some cases, however, the work of the contractor or grantee is complicated by unforeseen circumstances that impede the successful completion of the work as described in the original proposal.

In the case of prizes, there are no guarantees of successful completion by any of the teams in the competition. Especially in the case of competitions that are "first-to-demonstrate" in format, the competition may begin and end without a single successful entry. This was the case for the Orteig Prize that was originally issued in 1919 with a deadline of 1924. When the prize remained unclaimed as the time limit elapsed, Mr. Orteig decided to extend the competition for another five years, and it was in this second term of the competition that it was won by Charles Lindbergh in 1927.

In the case of "head-to-head" competitions which offer prize purses to the best entry that exceeds a set of minimum performance requirements, there is also no guarantee of a winner. This was also the case in the first year of the DARPA Grand Challenge. It is also possible that there will be more than one entry that will meet the minimum requirements of the competition, as was the case in the second year of the DARPA Grand Challenge.

Similarly, if more than one competitor shows up to a competition, it is likely that the designs and methods used to meet the competition requirements will be diverse and creative. Without the spectre of prejudgment, as exists in the proposal evaluation process of contracts and grants, competition participants will try new ideas and be more creative. Each design will be directly challenged through competition with other designs.

3. Successful Delivery

Maximizing the probability that a solution will be successfully generated in a contract or grant depends significantly on the ability of the proposal evaluators. To maximize the same probability for a prize competition, the rules must be written very carefully to ensure that the final result meets the original need. This is very important because once the rules are finalized, the funding organization has no control of the development path taken by the individual teams.

4. Eligibility

In the specific case of contracts, grants, and prizes as issued by NASA, there are certain barriers that include some individuals and companies, and exclude others.

In the case of NASA contracts and grants, proposers must follow contracting guidelines in the form of Federal Acquisition Regulations (most notably, part 12). For larger contracts, compliance with these regulations often requires a dedicated accounting and/or reporting staff and results in corporate overhead costs that are not common in small organizations.

In the case of NASA prize competitions, there are no onerous requirements that would exclude small organizations or individuals from participating, but there are geo-political and policy constraints that limit team leaders to citizens of the United States or companies incorporated in the United States.

5. Cost to NASA

In the case of NASA contracts and grants, the government will pay 100% of the cost proposed by the contract winner. In some cases, the government will pay more than 100% of the contract cost due to any number of factors or circumstances.

In the case of prizes, the prize purse is generally some fraction of what a contract would be worth to achieve the same results. Also, the government only makes a payment after somebody wins the competition by meeting all requirements as described in the rules.

6. Payment of Funds

Closely associated with the previous section is the payment schedule of the contract cost by NASA. Typical contracts have a payment schedule that NASA and the contractor agree upon. Typically, NASA will pay a certain fraction of the total contract cost on a monthly basis to the contractor based on a bill that accounts for actual expenses incurred during that period.

In a prize competition, 100% of the prize purse is disbursed only in the event that someone wins. If noone ever achieves the goals of the competition, no payment is ever made.

D. Lessons Learned From Prizes

Taken as a whole, the collection of historic accounts provides insights into the value and limitations of prize competitions. Some of the dominant themes as they relate to NASA are described below.

1. The Simpler, the Better

Challenges that are objective, simple, and unbiased are preferred over those that require complex rules, expensive testing and verification, and/or qualitative judging.

2. Relevance to NASA Programs

Challenges that develop and demonstrate capabilities that have strong relevance to NASA programs provide greater leverage to NASA programs and are more easily justified and preferred.

3. The Right Level of Difficulty

Many technical problems have multiple solution pathways. While it can be difficult to decide a priori which pathway is the best, a prize competition can allow more designs to be experimentally demonstrated than a standard contract or grant. Also, technical challenges that are too easy or too hard to achieve are not desirable.

4. Follow-On Opportunities

Historically, the most successful prize competitions are those that are aligned with some near-term economic opportunity for the competitors. All other things being equal, challenges that will produce a capability that can be

applied to a future NASA program, another aerospace market, or that have synergy with Earth-based applications are more desirable.

5. Competitor and Sponsor Interest

Interest from potential competitors and/or sponsors of the competing teams is a strong indicator that a particular prize competition may be a good candidate. Interest from potential co-sponsors of the prize purse itself (i.e., other organizations in the government, industry, and academia with research and development (R&D) interests coincident with NASA's) is another strong indicator.

6. Public Excitement

The most successful competitions produce excitement among the public, media, and educators. This excitement, in turn, encourages the participation of competitors and sponsors to earn their share of the fame associated with winning the prize. All other things being equal, challenges with greater potential to generate public excitement are more desirable.

7. Prizes are a temporary, "option #3" for non-existent productsSuperparanumonly

Prizes reward innovations that are publicly valued, but not privately marketed. Prizes arise from the demand for goods or services that are not available in the common marketplace and cannot be contracted out. If they existed, the free market or contracting solutions would be faster and more effective. Prize programs lose their utility once a successful market place or contracting capability has been created.

8. Prize programs cannot stand aloneSuperparanumonly

Business cases cannot be closed based on the cash purse alone. This explains why private investment often exceeds the value of the prize.

9. Prize programs require a delicate balanceSuperparanumonly

This is true for the size of the purse and for the development of the competition rules. Donors must offer a sufficient prize to attract a sufficient number of competitors and develop a solution in a desired time frame, but not so large as to diminish the cost benefit of the prize methodology. Similarly, prize rules must be specific enough to state the problem clearly, but not so specific as to stifle innovative solutions. They must also be hard enough to merit the purse award but not so hard that winning the competition is impossible.

II. Prize Culture

A. Cultural Elements

Below is a list of cultural elements with brief descriptions and examples of each.

1. Artifacts

Pieces of mechanical hardware that have been developed to win prize competitions are valued by society as physical evidence of the feat accomplished. Examples of prize-winning hardware include the John Harrison timepieces on display at the National Maritime Museum in Greenwich, England and the many aerospace vehicles hanging in the "Milestones of Flight" gallery of the Smithsonian's National Air and Space Museum in Washington, DC.

2. Stories

Many prize competitions are perfectly suited for story-telling because they pit a protagonist of low stature (i.e., common people, aka "mere mortals") against the antagonist of a very hard, sometimes very dangerous, and often seemingly-impossible feat (e.g., flying across the English Channel, flying across the Atlantic Ocean, or autonomously navigating over a desert without human intervention). Other pro/ antagonist pairings set the stage by matching the "little guy" against a "giant" as was demonstrated in the sign that read, "SpaceShipOne, Government Zero", after a successful flight of Burt Rutan's X PRIZE vehicle (see Figure 1).

FIGURE 1. SpaceShipOne and pilot Mike Melvil after a successful suborbital flight.

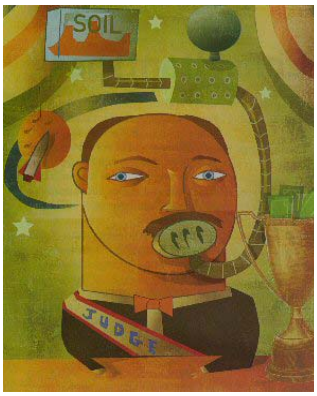

FIGURE 2. Symbols common to prizes include trophies and judges sashes, as shown in this depiction of NASA's MoonROx Challenge.

3. Rituals

Many prizes competitions are based on the theater of races, so they employ classic race rituals such as the "Ready, Set, Go!" of the starting line, and the awards ceremony to publicly present the winners with their honors. Other more modern rituals, such as "play-by-play" announcing or "color" commentary have been adopted by taking advantage of technology, allowing the event organizers to give the competition production of a television broadcast of a large-scale sporting event.

4. Heroes

It is clear that not all prize competition winners become "heroes" in world-wide popular culture, but it is true that the names of some do gain national and international recognition. The level of infamy may be related to the amount of personal risk that was assumed on the part of the individual compounded with the level of visibility the prize competition received from the general public. One of the most famous and recognizable prize winners in the United States and France is Charles Lindbergh. Popular opinion in Brazil and Europe recognizes Alberto Santos-Dumont as the father of aviation for accomplishing many daring "firsts" in the early days of European aviation.

5. Attitudes

Some prize culture characteristics that are common among many prize participants may be among the principle attitudes of the culture. These are described in detail in the next section.

6. Rules

It is clear that each prize competition is centered upon a specific set of rules, but some of these rules are common to all contests and are fundamental to the overall prize culture. Some of these "base" rules include the assumption of fairness and lack of bias in judging.

7. Symbols

Prize competitions have symbols that are easily recognizable and contain inherent meaning. Among these are:

- A starting and/or finishing line
- Judges, arbiters, or referees, especially as denoted by certain articles of clothing, such as a striped shirt or sash
- A trophy, depicting a non-monetary award
- A large-sized poster depicting a monetary check

Simple inclusion of these symbols into graphics or pictures conveys the concept of a competition (see Figure 2).

8. Beliefs

Like any subculture, there are beliefs held by its members. These are different than the rules mentioned above in that they are a common set of personal philosophies shared by the prize culture members. Members of the prize culture may believe that:

- They, as individuals or in groups, can solve difficult problems and receive due recognition for their efforts
- The assumption of financial and personal risk (sacrifice) to achieve a technical goal is a worthwhile way to spend their time and energy
- The risk posed by public demonstration of their intellectual property is so small that it does not deter their participation in prize competitions. (Individuals or groups who believe that the public demonstration of their technology makes the probability too high of losing their intellectual property rights will not participate in prize competitions).

B. Prize Culture Characteristics

Each of the following anecdotal lessons learned from prize history are discussed below and include:

- Democracy - anyone can participate and, potentially, win
- Creativity - only the performance of an idea counts, no matter how "outside the box" it may seem
- Inventiveness - the ability to combine existing elements to arrive at a new solution
- Persistence - never letting setbacks dampen the will to win
- Debt Relief - prizes can be an important way for the winners to pay off existing bills
- Risk-Taking - financial, professional, and even personal
- Inspiration - the feeling that "If somebody else could do it, so can I!"

1. Democracy

One of the advantageous aspects of prizes as a procurement instrument is that the winner of the competition is not selected before the technology is developed and demonstrated. It is not uncommon for prize winners to come out of nowhere and be the "underdog" or "dark horse" in the competition. John Harrison (a country cabinet-maker with no formal education, and winner of the Longitude Prize) and Charles Lindbergh (an unknown air-mail pilot, and winner of the Orteig Prize) are both good examples of how prizes don't necessarily favor notoriety or previous experience.

Prize competitions are a good way to identify and solicit ideas from previously-unknown sources of technical innovation. In contrast, typical government contracts and grants rely on a proposal selection process widely advertised among known (traditional) sources of innovation (e.g., industry, universities, and consultants). The government proposal selection process excludes individuals or companies that do not participate for many reasons (e.g. complexity of the proposal and contracting process, cost).

2. Creativity

Members of a traditional government contract or grant selection board will typically not select non-standard, non-traditional, innovative, or risky proposals for many legitimate reasons, including responsible stewardship of tax-payers' money and the impact a project's potential failure would have on future funding, as well as the proposed approach being too far outside the reviewer's experience base.

Throughout history, many prize winners have demonstrated a great ability to imagine, build, and demonstrate technologies that were "non-traditional," including John Harrison (solving what was thought to be an astronomical problem with a mechanical timepiece solution), Louis Blériot (before his successful "No. 11" aeroplane design, his first ten designs can only be described as "creative"), Paul MacCready (with his human-powered Gossamer Condor and Gossamer Albatross), and Burt Rutan (with demonstration of SpaceShipOne's hinged wing reentry, also known as "feathering", to increase stability and safety).

3. Inventiveness

Inventiveness can be defined as the property of taking existing components or ideas and combining them in new or different ways to create a solution. (Creativity differentiates itself as the same genesis of a new or different solution or methodology that is *not* based on existing ideas or components.) Inventiveness is an important trait of prize winners because it is a critical skill required for problem solving in general.

Many historic prize winners have demonstrated the value of inventiveness, and this is probably the most common trait of prize winners in general. Those who have demonstrated this ability include John Harrison, Alberto Santos Dumont, Louis Blériot, Charles Lindbergh, Paul MacCready, and Burt Rutan.

4. Persistence

Prize winners are typically not individuals who give up easily when faced with a problem whose solution is not immediately evident. One reason for the success of prize competitions often is because they feed the internal motivation within each competitor, to the limit of their psyche. People who are problem solvers tend to persist to a solution, especially when they have full ownership and control over the design and use of their solution.

Alberto Santos Dumont and Louis Blériot are examples of prize winners who went through many design iterations until they hit upon one that worked sufficiently well for them to win their prizes.

5. Debt Relief

In general, competitors in a prize competition are not participating for the money. In some cases, however, it *is* about the money. Louis Blériot, who became rich by manufacturing headlights for the newly-developed automobile industry, invested his personal profits from the company into his aviation hobby. He was on the verge of bankruptcy when he flew his No. 11 aircraft across the English Channel to win the £10,000 purse in 1909. Seventy years later, Paul MacCready was in debt when he decided to attempt to win the Kremer prize for the first human-powered flight of 1 kilometer in a figure-eight for a purse of £50,000 in 1977.

6. Risk-Taking

Almost by definition, teams participating in a prize competition are risk-takers. Because payment is not guaranteed and only happens at the end of the competition, teams often take on substantial financial risk. Many of the concepts promoted in the competition are previously untried or untested, so they are also taking technical risk. And, in cases where the competition requires that a device be operated manually or a vehicle be flown with someone on-board, teams take personal physical risk as well.

In contrast to prize competitions as a procurement instrument, risk-taking is an element that the typical government contract and grant procurement process attempts to eliminate.

7. Inspiration

Prize competitions that are won can generate a lot of publicity and recognition for the winning team. Some of that publicity stimulates like-minded individuals to think that *they* could have done what the prize-winner had accomplished. The general public tends to admire and want to emulate individuals that receive special recognition for achievement, especially when that recognition is accompanied by monetary compensation.

This side-effect of prizes can be used effectively to promote participation in future prize competitions or provide additional exposure for NASA programs. An entire category of Centennial Challenges competitions has been designed to entice individuals who have no prior special interest in such matters to get engaged briefly in scientific or technical subjects, and to interpret those subjects in a variety of ways. This program, dubbed “Quest Challenges,” has not yet been implemented.

C. Stereotypes of the Prize Culture

In response to the prize culture, the following are stereotypical remarks from traditional members of the contract and grant cultures:

- “The purse amount provided is not nearly enough to pay for the technology you want developed.”
- “The prize program and people competing in the prize are competition to traditional researchers and research programs.”
- “The people competing in the prize are hobbyists and amateurs, not serious scientists/engineers.”

Below is a discussion of each of these comments.

1. Insufficient Purse Amount

A typical response to a prize competition is that the value of the purse is not enough to cover the costs a team will incur to win it. This is usually true, but within the prize culture, it is practically irrelevant. Based on the strengths of prize competitions as a procurement instrument discussed previously, a business plan should rarely be able to be built upon a prize purse alone. There are cases where this has occurred (Charles Lindbergh’s costs were $10,000 less than the $25,000 purse), but such instances are rare.

Many prizes, however, are structured to position the purse as an inducement along a more lucrative path for the participating competitors. The business model that is more appropriate takes advantage of the purse as a "milestone payment" but relies more heavily on future contracts or open-market sales for some product or service developed in pursuit of the prize. That future compensation is the real prize money for the teams that participate, and not just the one that wins the prize. Prizes can be a means of creating a new market or industry base. That's where the real pay-off for the teams are and that is one of the major benefits of prizes.

Given this, how big does the incentivizing carrot need to be? History, both distant and recent, has shown that purses can be a minor fraction, even as little as 10%, of the estimated total cost of a project and still achieve successful results.

Ultimately, for most competing teams, the primary goal is rarely the prize purse, but a more lucrative pay-off after the prize is awarded.

2. Prizes are Competitors to Contracts/Grants

It is easy by some to understand how, especially in times of constricting budgets, a prize competition could be seen as a competing interest to government-funded research. For individuals and organizations alike, feelings of competition are inevitable when there are cuts in a research program that coincide with the initiation of a prize competition for similar research results. Presumably, this competition would result in some loss to the individual or organization, although it is probably impossible to quantify the loss with any accuracy if it even truly exists.

However, competition purses are typically of such small value, and could never provide meaningful offsets to program cuts experienced in times of shrinking budgets.

There is a different perspective embraced by many who see coincident research and prize activities as beneficial and worthwhile. Instead of seeing prizes as a competing force, prizes are seen as a means of inviting as many interested individuals and organizations as possible to participate in the subject research. From a competing team's perspective, one of the disadvantages to a prize competition is the requirement to demonstrate the entry publicly. This public display provides the opportunity to see who is doing the work, what they've done, and how they did it.

In this fashion, prize competitions can provide a form of "in-house research and development" to the traditional research community. The value of the prize competition outcome may depend greatly on how the traditional researchers perceive, approach, and deal with the prize competitors.

3. Prize Contestants are Unqualified

This sentiment flies in the face of a common, yet paradoxical, natural, human instinct that the value of something depends on what price it commands.

For example, it seems reasonable to assume that an individual in a group that is paid the highest salary is the most important or most qualified person, or performing the most important work in that group. However, it is not hard to imagine that another person within the same group that is paid much less could also be doing very important work. The highest paid individual is only perceived to be more important based on the rank of his or her salary.

Similarly, if someone or something is not very costly, then natural, human instinct leads us to believe that it is not very important, partly because it is inexpensive to replace.

As a simple example, if you have two appraisals for a piece of art and one appraisal cost $25, and the other cost $250, the more expensive appraisal is more likely to be of greater value than the less expensive appraisal. Even though they are both only pieces of paper with the opinion of an individual who may or may not be designated an "expert", the $250 appraisal will be taken more seriously than the $25 appraisal simply because it cost more.

But logic would indicate that there is no reason the $25 appraisal cannot be as valuable, if not more so, than the $250 appraisal. In fact, logic would dictate that the $25 appraisal should be *more* valuable than the $250 appraisal, because it cost ten times less.

But logic doesn't reign, and people think and act on the notion that less expensive is equal to lower quality, less value, etc. This same market logic pertains to prize competitions. Because the purse is so much lower than what the required technology would cost, the people pursuing the purses are perceived to be of lower qualification.

History has shown that although some of the participants of prize competitions may include non-traditional members outside the traditional technical communities, a successful prize competition makes no judgement on the provenance or credentials of the winner. Although the winners of many prize competitions throughout history were “sure bets”, there are plenty of examples of the winners being aptly described as “underdogs”, “dark horses”, and coming out of nowhere.

III. Centennial Challenges

Bolstered by the success stories of past prize competitions and knowing how prizes fit into technology development, NASA developed the Centennial Challenges program plan to maximize the benefits of prize competitions.

A. Origins of Centennial Challenges

In addition to the resurgence of prizes in the late 1990’s and early 2000’s (i.e., the Ansari X PRIZE and the DARPA Grand Challenge), the origins of the Centennial Challenges program can trace its roots to other influential documents and policies released or announced in approximately the same time frame.

1. 1999 National Academy of Engineering Report

In 1999, a panel was assembled by the National Academy of Engineering to provide guidance to the U.S. government on the use of inducement prizes to stimulate technological advances. The reportSuperparanumonly issued from this panel emphasized the historical importance and use of prizes in technology development, and urged their implementation by federal government research agencies. Specifically, they recommended that, “Congress encourage federal agencies to experiment more extensively with inducement prize contests in science and technology.”

2. Space Exploration Policy

In January 2004, a policy report entitled “A Renewed Spirit of Discovery - The President's Vision for U.S. Space Exploration”Superparanumonly was issued from the Office of the President of the United States. This report gave NASA a clear objective and goal, emphasizing the role of private industry in exploration by stating that NASA should, “promote…commercial participation in exploration to further U.S. scientific, security, and economic interests.” A presidential commission was also established at this time, and chaired by the Honorable E.C. “Pete” Aldridge, Jr., to make recommendations for the implementation of this policy.

3. Vision for Space Exploration

One month after the White House's space policy was issued, and the President verbalized the policy at a public event held at the NASA Headquarters building in Washington, D.C., NASA released “The Vision for Space Exploration,”Superparanumonly a report providing specific programmatic responses to the exploration directives. NASA's document established Centennial Challenges as a technology inducement prize program. Justification for its formation was that “NASA will need to leverage the ideas and expertise resident in the Nation's universities and industry…[by] establishing prizes for specific accomplishments that advance solar system exploration…”

4. Aldridge Commission

In June of 2004, the Aldridge Commission issued a reportSuperparanumonly that included findings and recommendations for the implementation of the exploration effort. Recommendation 5-2 from the report specifically states, “The Commission recommends that Congress increase the potential for commercial opportunities related to the national space exploration vision by providing incentives for entrepreneurial investment in space, by creating significant monetary prizes for the accomplishment of space missions and/or technology developments and by assuring appropriate property rights for those who seek to develop space resources and infrastructure.”

5. 2003 Space Architect Study

In preparation for the establishment of the Centennial Challenges program, NASA performed an internal study to identify and prioritize possible competition ideas. X PRIZE Foundation President Dr. Peter Diamandis and Executive Director Gregg Maryniak conducted interviews with NASA field center personnel from the field centers, compiled, and then analyzed the results. Their report was issued in November 2003 and identified 129 technology development

challenge ideas. Each idea was rated on criteria (e.g., alignment of technology development to NASA's mission) to produce a prioritized list. The top 20 ideas were then recommended for further consideration.

6. 2004 Centennial Challenges Workshop

The 2004 Centennial Challenges WorkshopSuperparanumonly was held on June 15 and 16, 2004 at the Hilton Washington hotel. In attendance were representatives from large and small industry, aerospace and non-aerospace, universities, government, and interested individuals.

Over two hundred attendees and 30 session moderators discussed generated ideas for future challenges in the areas of aeronautics, exploration systems, planetary systems, earth observation, bioastronautics, and astrophysics. Attendees and moderators also discussed potential rules and other details for over 30 competition ideas. The specific competitions were selected from the 2003 Space Architect Study results as well as ideas generated by workshop attendees in previous sessions.

Three guest speakers, including Senator Sam Brownback (Chair of the Commerce Subcommittee on Science, Technology, and Space), Dr. John Marburger (Director of the White House's Office of Space and Technology Policy), and Mr. Elon Musk (Founder and CEO of Space Exploration Technologies Corp.), discussed the importance of prize competitions in fulfilling the Vision for Space Exploration and NASA's ongoing missions. They also provided unique perspectives on the role of government and private industry in space technology development.

Three discussion panels were also conducted to provide workshop attendees with multiple viewpoints of the subject areas pertinent to technology development. The Launch Vehicle panel featured leaders of the nascent reusable launch vehicle industry. The Past, Present, and Future of Prize Competitions panel included brief presentations by prominent personalities who had direct experience with conducting or winning prize competitions. The Fund Raising panel featured descriptions of the sponsorship, venture capital, angel, and state subsidy communities.

B. Programmatic Description

NASA Centennial Challenges was established to conduct prize competitions in support of the Vision for Space Exploration and ongoing NASA programs. Centennial Challenges is modeled on past and ongoing prize competitions, including the 18th century British Longitude Prize; early 20th century aviation competitions, such as the Orteig Prize won by Charles Lindbergh; the ongoing DARPA Grand Challenge; and the recently won, privately-funded, Ansari X PRIZE. By implementing awards based on actual achievements instead of proposals, Centennial Challenges seeks novel and lower-cost solutions to engineering obstacles in civil space and aeronautics from new sources of innovation in industry, academia, and the public.

Eligibility to participate in Centennial Challenges competitions is open to participants who are not employees of the U.S. federal government or U.S. government organizations (including federally-funded research and development centers such as the NASA Joint Propulsion Laboratory). Participation of non-U.S. individuals or organizations as team members in a Centennial Challenges competition is allowed, but the team leader must be a U.S. citizen or organization.

C. Competition Structure

NASA plans four categories of prize competitions under Centennial Challenges: Flagship Challenges, Keystone Challenges, Alliance Challenges, and Quest Challenges.

Individual Challenges will take one of two forms: “first-to-demonstrate competitions,” like the Longitude Prize, Orteig Prize, and X PRIZE; and “repeatable contests,” like the DARPA Grand Challenge.

- Flagship Challenges - To encourage major, private space missions
- Keystone Challenges - To address key technology priorities at the subsystem level
- Alliance Challenges - To leverage partnerships to conduct smaller-scale Keystone Challenges
- Quest Challenges - To promote outreach and education in science, technology, engineering, and mathematics

1. Flagship Challenges

Flagship Challenges are intended to encourage external teams to independently design, develop, launch, and operate space missions, and thereby generate innovative and/or low-cost approaches to various civil-space goals that would not otherwise be pursued. It is envisioned that all Flagship Challenges will be “first-to-demonstrate” competitions with cash purses ranging from millions to tens of millions of dollars. Contributing to the overall purse may be co-sponsors with parallel capability or technology interests being pursued by the specific competition.

Flagship Challenges will be open to competitors from private sector companies, non-profit research institutions, university researchers, student teams, hobbyists, and any combination thereof. Examples of Flagship-type prize competitions include the Orteig Prize and the X PRIZE. Candidate Flagship Challenges under consideration by NASA include prize competitions for:

- A station-keeping solar sail
- A soft robotic lunar landing
- Low-cost robotic or human space missions

2. Keystone Challenges

Keystone Challenges are intended to encourage the development and demonstration of advanced technologies and/or innovative capabilities that support NASA's mission areas, and, where possible, have strong synergy with other applications. Keystone Challenges may be component-, subsystem-, or system-level demonstrations, and may involve robotic contests, drop tests, and/or atmospheric flight tests.

Depending on the technical goal, Keystone Challenges may take the form of “first-to-demonstrate competitions” or “repeatable contests”, with cash purses ranging from hundreds of thousands to millions of dollars. As in the case of Flagship Challenges, co-sponsors with parallel technology interests being pursued by the specific competition may contribute to the overall purse.

Keystone Challenges will also be open to private sector companies, non-profit research institutions, university researchers, student teams, hobbyists, and any combination thereof. The Longitude Prize and the DARPA Grand Challenge are two examples of Keystone-type prize competitions.

Candidate Keystone Challenges under consideration by NASA include:

- A mobile power storage breakthrough
- An autonomous drill
- A human, lunar, all-terrain vehicle

3. Alliance Challenges

An Alliance Challenge is identical to a Keystone Challenge, except that the prize is administered by an organization, at no cost to NASA, in exchange for the opportunity to be associated with the prize competition. Alliance Challenges are designed to leverage the capabilities of various non-profit organizations with domain expertise and/or members in the organization to administer a Challenge competition at no cost to NASA. Candidate Alliance Challenges for which NASA is seeking partners include any and all of the Keystone Challenges described above. Alliance Challenges are typically conducted on an annual basis with purses in the tens of thousands to hundreds of thousands of dollars.

4. Quest Challenges

Quest Challenges are intended to complement other Challenge categories by promoting science, technology, engineering, and math (STEM) awareness, subjects, and careers to youth and other age groups. Quest Challenges, categorized by and targeted to people of all different groups, are designed to be inspirational and enriching. Some Quest Challenges involve individual or group activities, repeatable contests, or submission of entries for judging. Purses for Quest Challenges are designed to be of interest to the targeted age groups, and include either cash or experiential awards. Examples of Quest Challenges include:

- Relevant student science competitions, such as the Intel Science Talent Search
- Science, Technology, Engineering and Math-related games and tournaments, such as internet-based games, card games, and video games
- Best of Science/Science Fiction Challenges in a wide variety of the arts (e.g., literature, visual, motion picture, music, etc.)

D. Current Centennial Challenges

After conducting the workshop in 2004, NASA focused its attention to developing and initiating multiple competitions during 2005. Due to spending authorization limitations that were not lifted until December 30, 2005, all the competitions announced to date have purse values of $250,000 or less, and fall into the category of Alliance Challenges.

A table and brief description of the complete set of past and present competitions is provided below

TABLE 2. Table of Past and Current Centennial Challenges Competitions

Prize Competition	Purse Amount	Alliance Organization (website URL)	Event Date(s)
Beam Power	$200K	The Spaceward Foundation (www.spaceward.org)	October 2005, October 2006
Tether	$200K	The Spaceward Foundation (www.spaceward.org)	October 2005, October 2006
Regolith Excavation	$250K	California Space Authority (www.californiaspaceauthority.org)	May 2007
MoonROx	$250K	Florida Space Research Institute (www.fsri.org)	Expires June 1, 2008
Personal Air Vehicle	$250K	Comparative Aircraft Flight Efficiency Foundation (www.cafefoundation.org)	June 2007
Telerobotic Construction	$250K	The Spaceward Foundation (www.spaceward.org)	October 2007, October 2008
Astronaut Glove	$250K	Volanz Aerospace / Spaceflight America (www.spaceflightamerica.org)	April 2007
Planetary UAV	$250K	California Space Authority (www.californiaspaceauthority.org)	May 2008
Lunar Lander	$2M	The X PRIZE Foundation (www.xprize.org)	October 2006 - October 2010

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1. Beam Power

The Beam Power Challenge is designed to promote the development of new, high-density, power distribution technologies that have applications to many aspects of space exploration, including surface- or space-based, point-to-point power transmission, or delivery for robotic and/or human expeditions to planetary surfaces. For the event, each team will build a vehicle, or "climber," that will ascend and then descend a 60-meter ribbon suspended by an overhead crane. The climber's power source is located at the bottom of the tether. Each climber will have three opportunities to climb the tether, carrying some amount of payload at a speed of at least 1 meter per second. The purse will be won by the team that has the highest score (the product of average speed and payload mass, divided by climber mass).

2. Tether

The Tether Challenge is designed to promote the development of new, high strength-to-weight materials that have the potential to dramatically affect engineering solutions in a wide variety of applications, including space exploration. It is conducted in two rounds: a single-elimination tournament first-round to determine the team with the strongest tether from among all the entries with a mass of 2 grams, and the final, pull-off, second round, when the first round winner must compete against a "house tether," representative of current commercial, off-the-shelf, state-of-the-art

materials, with a mass of 3 grams. To win the purse, the strongest team tether must show a 50% increase in strength-to-weight by beating the house tether.

3. Regolith Excavation

The Regolith Excavation Challenge promotes the development of new technologies to excavate lunar regolith. Excavation is a necessary first step towards lunar resource utilization, and the unique physical properties of lunar regolith make excavation a difficult technical challenge. Advances in lunar regolith extraction have the potential to contribute significantly to the nation's space exploration operations. Teams competing in this competition will build autonomously operating systems to excavate lunar regolith and deliver it to a collector. This challenge will be conducted in a "head-to-head" competition format. Teams will be challenged to excavate and deliver as much regolith as possible in 30 minutes.

4. Moon Regolith Oxygen (MoonROx)

The MoonROx Challenge is designed to promote the development of essential lunar propellant extraction technologies, and results in a monetary award to the winning team. The challenge is to extract 2.5 kilograms of oxygen in four hours from lunar regolith simulant, JSC-1. The MoonROx Challenge is structured as a "first-to-demonstrate" competition. Teams will register for the competition, but there will not be a pre-scheduled event where they all come together to compete against each other. Instead, teams will work independently of each other. When one team has completed their work, they will notify the Florida Space Research Institute to schedule a demonstration of their hardware. At the demonstration, FSRI will provide the necessary materials (such as regolith simulant) and infrastructure (such as power), and the team will be given the opportunity to demonstrate their competition entry according to the rules of the competition. If the team meets or exceeds all of the requirements of the MoonROx competition, they will win the $250,000 purse. If the team fails to meet the requirements, the competition will remain open until a successful attempt takes place. If no team wins the purse before June 1, 2008, the contest will expire and no further attempts to win the prize will be considered.

5. Personal Air Vehicle (PAV)

The Personal Air Vehicle (PAV) Challenge is intended to promote the popular use of self-operated, personal aircraft for fast, safe, efficient, affordable, environmentally-friendly, and comfortable on-demand transportation as a future solution to America's mobility needs. Entrants will be accepted into the competition only after demonstrating the capability to meet all minimum eligibility requirements during qualifying flight tests at the Comparative Aircraft Flight Efficiency Foundation's flight test facility. The PAV Challenge will award a total purse of $250,000, which is divided into one PAV Prize and four prizes for outstanding achievement in four areas.

6. Telerobotic Construction

The Telerobotic Construction Challenge is designed to advance the development of robust technologies of human-robot interactions. NASA hopes to use these technologies to efficiently build structures for astronauts sent to live or work in them, on the Moon or other remote destinations. The Telerobotic Construction Challenge will be conducted by teams of people and robots working together to construct a standardize modular structure. Teams will operate their robots remotely, using video and data communications that have time delays and limitations, simulating Earth-to-Mars distances. One major goal of the competition is to determine to what level the robots need to be able to work together on their own, based on the limited amount of communication time and data provided to the human controllers.

7. Astronaut Glove

The 2006 Astronaut Glove Challenge is designed to promote the development of glove joint technology, resulting in a highly dexterous and flexible glove that can be used by astronauts over long periods of time for space or planetary surface excursions. The 2006 Astronaut Glove Challenge will be conducted by Volanz in a format that brings all competitors to a single location for a "head-to-head" competition to determine the winning team. Each team will be required to perform a variety of tasks, and will be scored on their performance. The team that earns the highest score will be the winner and be awarded the $200,000 purse. A $50,000 prize will also be available for the demonstration of improvements in mechanical counterpressure glove technologies.

8. Planetary Unmanned Aerial Vehicle (PUAV)

The Planetary Unmanned Aerial Vehicle Challenge is designed to promote the development of fully autonomous Unmanned Aerial Vehicles (UAV's) capable of conducting scientific expeditions on other planets and moons within our solar system. In addition to the application of this technology to space science, there are secondary applications to Earth science, homeland security, and humanitarian and commercial endeavors. The goal of this challenge is to develop and demonstrate long-duration, autonomous flight. This capability may one day be used to collect scientific samples on other planets. One of the more difficult aspects of the PUAV challenge is the need for full autonomy and visual navigation. The PUAV Challenge will pit multiple vehicles against each other in time trials around a flight course, where the vehicle must perform a series of difficult tasks.

9. Lunar Lander

The $2 million Lunar Lander Challenge is designed to accelerate technology developments supporting the commercial creation of a vehicle capable of ferrying cargo or humans back and forth between lunar orbit and the lunar surface. Such a vehicle would have direct application to NASA's space exploration goals as well as the personal spaceflight industry. Additionally, the prize will help industry build new vehicles and develop the operational capacity to operate quick-turnaround, vertical take-off, and vertical landing vehicles, which will be of significant use to many facets of the commercial launch procurement market.

IV. Conclusion

Prizes have been used throughout history as a way to stimulate technology development with unexpected positive results for a fraction of what an equivalent contract would cost. Prizes have encouraged individuals, companies, and governments to achieve seemingly impossible goals. The popularity of prizes in the first part of the twentieth century and its resurgence in the present day have increased the membership in a "prize culture" that has led to stereotypical reactions by the traditional science and engineering communities. As is common with any stereotype, these contain some level of "truthiness," but once examined closely, these stereotypes can be seen to link the traditional R&D and prize communities together. The Centennial Challenges program builds on the positive forces of prize competitions in an attempt to pursue NASA's mission and goals in an exciting, innovative, and cost-effective way.

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